MESOPREDATOR ABUNDANCE IN OAK FOREST PATCHES: A COMPARISON OF SCENT STATION AND LIVE-TRAPPING TECHNIQUES

By

MICHAEL ROY DISNEY

Bachelor of Science

Oklahoma State University

Stillwater, OK

2001

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 2005

MESOPREDATOR ABUNDANCE IN OAK FOREST

PATCHES: A COMPARISON OF SCENT

STATION AND LIVE-TRAPPING

TECHNIQUES

Thesis Approved:

Eric C. Hellgren

Thesis Adviser

Craig A. Davis

David M. Leslie, Jr.

A. Gordon Emslie

Dean of the Graduate College

PREFACE AND ACKNOWLEDGMENTS

The purpose of this study was to assess the relationship between mesopredator relative abundance and size of mixed oak patches in the Oklahoma Crosstimbers Region. Estimates of mesopredator relative abundance from live traps and scent stations also were compared.

This project and thesis would not have been possible without the dedication and guidance of my adviser Dr. Eric Hellgren. His professionalism and standard of excellence were the gears that moved the project along. I also thank committee members Dr. Craig Davis and Dr. David (Chip) Leslie, Jr. for their input and support throughout the entire project. Special thanks go to Dr. Leslie and the Oklahoma Fish and Wildlife Research Unit for the use of the field vehicle that was unfortunately forced to retire after many years of service on CTER. Other contributions during the study came from technicians and friends in the field that suffered through heat, ticks, and chiggers to help me check traps. Here's to you: Luke Bell, Donnie Bradford, Roy Churchwell, Marc Criffield, Evan Comer, Chrystal Davis, Tim Langford, Jill Sporrong, Zach Ritter, Heather Thurston, and David Walter for all the hard work.

Just when I thought that graduate school was all work and no play, fellow students and faculty members from the Zoology Department were there to buy a game of pool at happy hour or open their houses for the many antics involved with departmental socials. Thanks go out to everyone in Life Sciences West for the good times between research and class. Special thanks goes to my good friend Marc Criffield and the many laughs we had both in the field and the office, I hope there are more to come.

Family members that have regrettably gone before me and not been able to share many of life's adventures include my mother and my grandfather "Grandpa Roy." I know that they look down on me today and have only one thing on their mind, "What's next?" I hope to continue walking in their footsteps so that some day I may reach the potential they always told me I had. I also want to thank my father whose life-long struggle with mental illness has attempted to bring him to his knees. His love for the natural world deserves most of the credit for who I am today. He bought me my first fish tank when I was still in diapers.

Finally I am most grateful to my loving wife Brooke. You have always seen me for who I am and not just for what I have done. Thank you for sticking with me and realizing that the future holds some great things for us. I love you….

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

INTRODUCTION

Fragmentation of habitats may result in changes in wildlife community structure and abundance of species present within individual habitat patches (Yahner 1988). Expansion and intensification of human land use are the leading cause of habitat fragmentation (Andren 1994). Landscape manipulation through urban sprawl and agricultural utilization reduces large-scale habitats to isolated patches, eliminating available habitat for large carnivores (e.g., gray wolf [*Canis lupus*], mountain lion [*Puma concolor*]) that require continuous areas to survive (Matthiae and Stearns 1981). Researchers have postulated that with the removal of large carnivores, mesopredators such as raccoons (*Procyon lotor*), Virginia opossums (*Didelphis virginiana*), striped skunks (*Mephitis mephitis*) and red fox (*Vulpes vulpes*) will increase (Rogers and Caro 1998). This idea has been coined "The Mesopredator Release Hypothesis." Also referred to in the literature as mesocarnivores, mesopredators can represent the highest trophic level in areas devoid of larger predators (Shirer and Fitch 1970). Mesopredators are generalists, finding suitable habitat and nutrient needs in a variety of habitat types and environments (Godin 1982, Kaufman 1982, Gardner and Sunquist 2003). They typically have omnivorous diets consisting of available prey species, carrion, invertebrates and many types of plants (Rosatte 1987, Sanderson 1987, Seidensticker et al. 1987).

As habitat fragmentation increases, so does the proportion of habitat edge within an area. Forest-agricultural edges provide significant habitat to mesopredators (Donovan et al. 1997). These fragmented landscapes cause an increase in habitat diversity, which has led to an increase in populations of generalist predators (Oehler and Litvaitis 1996). Dijak and Thompson (2000) reported that raccoons were more abundant in forest edges adjacent to agricultural fields and streams in Missouri. Edges also provide viable habitat to some nesting birds, creating a condition known as an ecological trap, whereby species are attracted to an area due to increased habitat diversity but exhibit decreased reproduction and survival due to increased predation of predators within the area (Gates and Gysel 1978). The ecological trap hypothesis should be viewed with caution because it cannot be applied to all wildlife communities with increased edge habitats. For example, artificial nests that were placed within a low-density pattern in Idaho received more predation than nests in a high-density pattern, thus contradicting the idea of an ecological trap (Ratti and Reese 1988).

There is growing concern within the scientific community over mesopredator abundance along these edges because nesting birds may become easy prey for foraging mesopredators. Winter et al. (2000) found that mesopredator predation rates doubled when nests were within 15 m of forest edge compared with predation rates of nests 30-45 m from edge habitat. Increased nest predation along forest edges has been observed, but conclusions as to why or how this occurs have not been reached (Zegers et al. 2000).

Researchers have proposed many hypotheses to explain increased predation rates near forest edges (Yahner and Scott 1988, Robinson et al. 1995, Donovan et al. 1997). Hypotheses include: (1) presence of mesopredators may increase near edges due to high prey density (Ratti and Reese 1988); (2) predator density may be greater near edges than in forest interiors (Angelstam 1986, Pedlar et al. 1997); (3) the predator community may be richer in species along edges than forest interiors due to increased biodiversity (Temple and Cary 1988, Marini et al. 1995); and (4) predators may forage along travel lanes such as edges (Yahner and Wright 1985, Small and Hunter 1988, Marini et al. 1995). Studies have supported and refuted these hypotheses, but due to differences in experimental designs, clear conclusions cannot be made from data gathered (Paton 1994).

Another consequence of fragmentation and increased edge is reduced size of habitat patches. Therefore, patch size is another variable of interest in evaluating relationships between nest predation and mesopredator abundance. Hoover et al. (1995) found that nesting success of wood thrush (*Hylocichla mustelina*) increased with forest patch size. Predation levels and visitation rates of mammalian predators at scent posts within these forest patches increased as patch size decreased. By comparing levels of abundance of mesopredators–known predators of nesting birds–within different-sized forest patches, we may begin to understand how patch size and edge:area ratios affect nesting success of forest bird species.

OBJECTIVES

1) To assess the relationship between mesopredator relative abundance and size of mixed oak patches in the Oklahoma Crosstimbers Region.
2) To compare estimates of mesopredator relative abundance by live-trapping and scent- station visitation.

LITERATURE REVIEW

Mesopredators and Fragmented Habitats

The Crosstimbers Ecosystem of Oklahoma is characterized by a mosaic of post oak (*Quercus stellata*)-blackjack oak (*Quercus marilandica*) forest and grassland with an increasing density of eastern redcedar (*Juniperus virginiana*; Ewing et al. 1984). Within these forests, the most common mesopredators recorded are raccoon, Virginia opossum, and striped skunk (Levesque 2001). These habitat generalists are found throughout the United States and have an affinity for anthropogenically disturbed landscapes and heterogeneous habitats (Oehler and Litvaitis 1996). In Missouri, raccoons preferred forested habitats with high stream density and were closely associated with agricultural fields; opossum abundance increased with stream density; and striped skunk abundance was not affected by any measured landscape characteristic (Dijak and Thompson 2000).

Low reproductive success of many passerines is attributed to predation associated with increased mesopredator abundance in fragmented habitats (Martin 1993, Donovan et al. 1995, Robinson et al. 1995). Donovan et al. (1997) determined that nest predation rates from avian and mammalian predators relative to habitat edge were high both within the interior and edge of highly fragmented forests, low within the interior but high within edges of moderately fragmented forests, and low in both interior and along edges of contiguous forests. From those data, Donovan et al. (1997) concluded that predation rates of forest-nesting birds increased with increased fragmentation.

Researchers have suggested 4 hypotheses to explain why predation rate increases along forest edges. First, the presence of mesopredators may increase near edges due to high prey density. Ratti and Reese (1988) tested this hypothesis found that artificial nests placed in low-density patterns along forest field edges were preyed on more often than nests placed in high-density patterns in the same area. That result contradicted the idea that predators are attracted to high prey densities, thus supporting research that found no evidence of increased predation due to high prey density (Dunn 1977, Page et al. 1983). Ratti and Reese (1988) suggested, however, that predation on nests may reach a saturation point and further investigation is needed to determine if this was a factor in their study.

A second hypothesis describing increased predation near edges suggests that predator density may be greater near edges than in forest interiors. Pedlar et al. (1997) measured raccoon habitat use in Canada using scent stations. Raccoons frequently occurred in: (1) woody vegetation features associated with fencerows, den trees, and deciduous stands; (2) macrohabitats with extensive agricultural edge; and (3) wooded remnants in areas with extensive corn cover. These results support the idea that predator density may be greater near edges than in forest interiors. Conversely, Heske (1995) showed no difference in abundance of furbearers within forest-farm edges and forest interiors in Illinois. Heske (1995) advised that the generality of the "edge effect" concept be used with caution.

The third hypothesis to explain increased predation near habitat edges states the predator community may be richer in species along edges than forest interiors. Predator richness was measured by Marini et al. (1995) in forest-farm edges and forest interiors. Species richness among mammalian predators did not differ between forest-farm edges and forest interiors. However, avian predator richness including species such as blue jays (*Cyanocitta cristata*), American crows (*Corvus brachyrhynchos*), and common grackles

(*Quiscalus quiscula*) increased in edges compared with forest interiors. These results are similar to findings by Angelstam (1986), who found habitat utilization varied among nest predators in his study. Conclusions from Marini et al. (1995) should be viewed with caution due to small sample sizes.

A final hypothesis states that predators forage along travel lanes such as edges, which thereby results in increased encounters with ground-nesting birds. Dijak and Thompson (2000) found that fragmented forests used for foraging, such as agricultural edges, provide abundant foods resulting in increased raccoon abundance and detection rates. Moderately-sized patches of grassland in northern Iowa seemed to have increased activity rates by foxes, whereas smaller, isolated patches of grassland had average fox activity (Kuehl and Clark 2002). An increase in fox activity along straight grassland edges provided evidence that these features may be used as travel lanes. Small and Hunter (1988) also supported the travel lane hypothesis, suggesting that mesopredators may be moving into small forests from surrounding lands, possibly using edges of power lines and roads as travel corridors.

Marini et al. (1995) could not support the travel-lane hypothesis because predation levels were higher on ground nests placed far from roads and ravines compared with nests placed near them. Depredation of songbird nests by mesopredators may be incidental (Heske et al. 1999). These predators likely prey on nests after encountering them during other foraging activities. This suggestion is supported by Vickery et al. (1992), who reported an apparent increase in incidental nest depredation by skunks during increased foraging activities. Based on previous research, it remains difficult to conclude that any single factor influences why predation rates increase near edges.

A landscape mosaic comprises numerous habitat patches. Sovada et al. (2000) found that daily survival rates of duck nests in Minnesota increased with habitat patch size. In contrast, activity indices of red fox increased as patch size decreased. Wilcove (1985) conducted similar research focusing on nest predation in 11 forest patches (size range: 3.8-905 ha) in Maryland and southeastern Tennessee. He found that nest predation was higher in smaller forest patches. Small and Hunter (1988) used artificial nests in Maine to measure predation rates within different-sized patches of forest habitat and found that predation increased in small forest patches. Similarly, Wilcove (1985) noted thatactivity by small predators may be greater in small woodlots than in larger forest fragments.

Previous studies also suggested that presence of an individual species within a patch may not only be dictated by characteristics of the patch itself but by neighboring habitats. Habitat heterogeneity across landscapes increases with habitat fragmentation. Size of an individual species' home range may allow it to use many components of a landscape mosaic.

Scent Stations as Population Indices

Effective methods of estimating mesopredator abundance within habitat patches include mark-recapture using live traps (Lancia et al. 1994) and scent-station visitation (Conner et al. 1983). The latter technique has come under scrutiny, and researchers suggest continued analysis of scent station indices in estimating population abundance (Conner 1984).

The scent station is a practical method to determine trends in carnivore populations (Roughton and Sweeny 1982). It was originally developed to determine relative abundance of red and gray (*Urocyon cinereoargenteus*) foxes (Wood 1959) but has been used for coyotes (*Canis latrans,* Linhart and Knowlton 1975), bobcats (*Felis rufus,* Conner et al. 1983), wolves (*Canis lupus,* Pimlott et al. 1969), river otter (*Lutra canadensis*) and mink (*Mustela vison,* Humphrey and Zinn 1982), San Joaquin kit fox (*Vulpes macrotis mutica*, Warrick and Harris 2001), and raccoons (Conner et al. 1983). Although use of the scent-station technique is widespread (Nottingham et al. 1989), some researchers consider it an unproven tool (Minser 1984). It indicates species presence but does not allow the researcher to distinguish among individuals within a species (Heske 1995). Researchers using relative abundance data from scent-station visitation rates assume that the relationship between visitation rate and density of a given species is sufficiently consistent for the index to provide reliable and useful information (Sumner and Hill 1980).

Researchers value the scent-station technique because it is a cost-effective method of assessing carnivore abundance over large land areas (Sargeant et al. 1998). Debates within the scientific literature have focused on the validity of scent stations as population indices (Conner 1984, Minser 1984). Smith et al. (1994) were unable to predict abundances of raccoons in Tennessee from scent-station visitation rates in populations with fluctuating densities. They concluded that visitation rates among individual raccoons varied with changes in population density and visits to scent stations either underestimated or overestimated abundance. However, Conner et al. (1983) concluded that scent-station indices accurately reflected trends in population abundances of bobcats, raccoons, and gray foxes, but not opossums.

Recommendations for standardizing scent-station methodologies (Conner et al. 1983) include using scent stations when visitation of the species of interest is the highest; Smith et al. (1994) observed highest rates of raccoon visitation in spring and summer in Tennessee. Second, scent stations within transects should be spaced at 0.32 km to indicate trends in population abundances of bobcats, raccoons, and gray foxes. Third, distribution of transects should sample all major habitat types proportionately. Minser (1984) commented on the work of Conner et al. (1983) and concluded that it was impossible to assume scent-station visitation rates reflect changes in population density without first measuring population densities at least twice by means of live trapping. Conner (1984) replied by suggesting his previous work was an initial step toward evaluating the relationship between changes in furbearer abundance and corresponding changes in scent-station indices. To determine the validity of scent stations used as population indices, studies must be conducted by comparing data gathered by scent-stations with data gathered from population estimation techniques such as mark-recapture methods.

Roughton and Sweeny (1982) provided detailed recommendations concerning the proper methods and analysis of scent-station data. Design features should include lines of 10 scent stations that are used for only 1 night and new lines should be established daily to maximize scent station distribution and minimize repeated visits by individual animals. Scent stations should be graded flat with all vegetation and rocks removed. Smith et al. (1994) suggested using an imprint of your knuckles in the substrate as a reference track to determine if favorable conditions occur. Timing of scent station surveys is very important (Roughton and Sweeny 1982). Hunting seasons that increase traffic within study areas and seasons with adverse weather should be avoided. Intervals between scent stations should be scaled to mobility of the species of primary interest and size of the study area. Scent stations should be appropriately spaced to avoid the chance of individual animals visiting >1 line in a night (Roughton and Sweeny 1982).

Preliminary field tests should be conducted to determine the most suitable attractant for the species of primary interest. Fatty acid scent is an excellent canid attractant and is recommended for use with other carnivores (Roughton and Sweeny 1982). Other studies using bobcat urine as an attractant obtained reliable visitation rates by mesopredators (Conner et al. 1983, Nottingham et al. 1989). The attractant must have uniform ability to attract individuals throughout each survey. A saturated plaster disc is recommended as a low-cost, convenient means of presenting attractant (Roughton and Sweeny 1982). Nottingham et al. (1989) and Conner et al. (1983) used saturated cottonballs to present attractant. Attractants should be removed immediately following surveys to reduce chances of individuals becoming habituated to the attractant (Roughton and Sweeny 1982).

STUDY AREA

The Cross Timbers Experimental Range (CTER) is located about 11 km southwest of Stillwater, Payne County, Oklahoma (Ewing et al. 1984). Livestock grazing and lease hunting are the main economic land uses in the area. The area was originally characterized by a mosaic of grassland, savannah, oak thickets, and dense woodlands (Engle et al. 1996). Since settlement, however, increased cattle grazing has limited the accumulation of fine fuels, eliminating recurrent intense fires within the area. With the removal of fire, a closed canopy of trees developed, thereby further reducing the likelihood of fuel accumulation necessary for intense fires (Stritzke et al. 1991).

Vegetation of the area includes a mosaic of upland forest dominated by blackjack oak (*Quercus marilandica*) and post oak (*Q. stellata*); tallgrass prairie; and bottomland forest composed of shumard oak (*Q. shumardii*), American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), black walnut (*Juglans nigra*), and hackberry (*Celtis* spp.). Understory woody species in upland and bottomland forest include eastern redcedar, poison ivy (*Rhus radicans*), rough-leaf dogwood (*Cornus drummondii*), redbud (*Cercis canadensis*), and American elm. Dominant species in the herbaceous layer include little bluestem (*Schizachyrium scoparius*), Indiangrass (*Sorghastrum nutans*), big bluestem (*A. gerrardii*), and rosette panicgrass (*Panicum oligosanthes*) (Ewing et al. 1984).

The CTER has been used to evaluate techniques in vegetation management since 1983. These techniques include herbicide application and prescribed fire (Engle et al. 1991, Stritzke et al. 1991). Current (2005) vegetation types in CTER and surrounding areas are redcedar forest, derived grassland, scrub-shrub community and mature oak forest (Levesque 2001, Ginger et al. 2003). My study involved patches of post oak-blackjack oak forest in CTER and surrounding landscape.

METHODS

Patch Selection

I delineated 20 patches of oak forest ranging from 0.2 to 55.3 ha with the use of aerial photos and vector GIS (Fig. 1). Using ground-truthing, I ensured that a non-forested gap of $\geq$10 m (the width of a county road) existed between patches. Scent stations and live trapping were used in these patches.

Trapping and Handling

I used Tomahawk® (Tomahawk Trap Company, Tomahawk, Wisconsin, USA) wire mesh traps (25 x 30 x 81 cm) to trap mesopredators. In 2003 and 2004, I conducted 2 trapping periods in the summer (May-Aug) within each patch. A trapping period lasted 10 consecutive days. Each trap was baited with sardines and checked 24 h later. Traps were spaced 100 m apart within the oak-forest patches. Within patches containing >3 traps, transects sampled from the edge to the interior of the patch. Trap density in each patch ranged from 0.25 to 0.50 traps/ha.

Captured individuals were identified to species, anesthetized with Telazol® (tiletamine hydrochloride and zolazepam hydrochloride; Fort Dodge Animal Supply, Fort Dodge, Iowa, USA) at 8 mg/kg estimated body mass and ear-tagged with 2 #4 Monel® tags (National Band and Tag, Newport, Kentucky, USA). Individuals were sexed, aged (adult, juvenile), and weighed (kg) with a spring scale (Douglas Homs Corporation, Belmont, California, USA). Opossums were aged according to tooth eruption; presence of all 4 molars indicated an adult, which are present in opossums 9-10 months after birth (Gardner 1982). Female raccoons were aged according to teat development; post-nursing individuals were classified as adults (Kaufmann 1982). Male raccoons were aged according to baculum length; male raccoons with a baculum length of $\geq$ 90 mm were classified as adults (Kaufmann 1982). Male striped skunks were classified as adults if the baculum was $\geq$ 19 mm in length; female striped skunks were classified as adults according to teat development (Godin 1982). Aftercapture, individuals were marked w ith

2 uniquely numbered ear tags and released back into the population. I returned the following day to check for mortalities among newly captured individuals. A capture history was maintained for each individual. Capture and handling procedures were approved by the Institutional Animal Care and Use Committee of Oklahoma State University (Protocol AS50179).

Scent Stations

Scent stations consisted of a 1 x 1-m sheet of plywood covered with firewood ash to record tracks left by individuals visiting the station. A cotton ball saturated with bobcat urine positioned in the middle of the ash was the attractant. Scent stations were placed $\geq$ 100 m apart within trap-line transects. Scent station density in each patch ranged from 0.25 to 0.50 stations/ha.

I conducted surveys in 2 sampling periods in the summer (May-Aug) within each patch during each year. Scent stations were activated and remained open for 1 night. Results were recorded the following day. This process was continued for 3 days. Relative abundance was estimated according to methods used by Leberg and Kennedy (1987):

$$\text{Relative Abundance Index (RAI)} = \frac{\text{Total station visits}}{\text{Total operable station nights}} \times 1{,}000.$$

Microhabitat Variables and Analysis

Vegetation was measured at each trap and scent station during summers 2003 and 2004. Understory cover was estimated in Daubenmire cover classes (Bonham 1989) in a 1-m^2 plot at each trap and scent station site and 1-m^2 plots 10 m from the trap and scent station sites in northeast (45º), southeast (135º), southwest (225º), and northwest (315º) directions (Fig. 2). Data collected included percent cover of forbs, grass, woody vegetation ($\leq$ 0.5 m in height), moss, hardwood leaf litter, bare ground, rock, and miscellaneous litter (e.g., eastern redcedar leaves, twigs). I collected 4 measurements of canopy cover and visual obstruction at each 1-m^2 plot at each trap and scent station site using a densiometer (Bonham 1989) and 1-m tall board with alternating 0.1-m, dark and light blocks, respectively. The visual obstruction board was placed 4 m from the trap/scent station point in 4 directions: northeast (45°), southeast (135°), southwest (225°), and northwest (315°). All measurements at each site were averaged. Only blocks completely obstructed were counted (Levesque 2001). I measured diameter at breast height (dbh) of each stem $\geq$5 cm and tree condition (live, snag, standing stump) and recorded counts of coarse woody debris ($\geq$ 10cm dbh) in an 8.93-m-radius circular plot (0.025 ha) centered at each trap/scent station site (Fig. 2). Basal area (m^2/ha) was calculated for each group of tree species (eastern redcedar, oak, nonoak deciduous, and total) for each trap and scent-station site. Stem density of woody stems $\leq$ 5 cm was measured using a 2 x 20-m belt transect across the circular plot. Terrain position code (lower, mid or upper slope) and aspect were recorded for each trap and scent-station site (Ginger 2002).

Each trap and scent station location was georeferenced using a hand-held Global Positioning System (GPS; Garmin Etrex Navigation Sytems, Olathe, Kansas, USA) and overlaid into a geographic information system (GIS) via Arcview 3.3 (Environmental Systems Research Institute, ESRI, Redlands, California, USA). Using Arcview 3.3 (ESRI) and a digitized 2003 National Agriculture Imagery Program (NAIP) aerial photo of CTER, I calculated distances from each trap and scent station to nearest forest patch edge, dirt road, improved road, and paved road. I compared microhabitat variables at each trap and scent station where raccoons and opossums were present for each year with those at sites where these species were absent using unpaired *t*-tests (PROC TTEST; SAS Institute Inc. 1990).

Macrohabitat Variables and Analysis

Using Arcview 3.3 (ESRI), polygons representing the 20 forest patches were overlaid onto a classified 1992 Landsat Thematic Mapper satellite image provided by the U.S. Geological Survey. The Landsat TM image provided land-cover data for areas surrounding each of the forest patches (Table 1, Fig. 3). Using the Buffer Wizard in Arcview 3.3 (ESRI), a 500-m buffer was applied to each forest patch polygon. Each buffer represented the radius of a 78.5-ha circle, which approximates an average home range of a female raccoon (Gehrt 2003). Opossum ranges are typically smaller or similarly sized to female raccoons (Gardner and Sunquist 2003). Zonal Statistics in Arcview 3.3 (ESRI) provided the percent cover of each land-cover class within the 500-m buffers in the Landsat TM image. Patch Analyst in Arcview 3.3 was used to calculate the edge-to-interior ratio of each of the forest patches (Table 1).

Linear Regression Models.— Relative abundance data (unique captures/100 trap nights for live-trapping effort or RAI for scent stations) by patch (n = 20) were regressed against forest patch size (PROC REG; SAS Institute Inc. 1990). Scent station RAIs also were regressed against capture rates to examine the relationship between these measurements of relative abundance.

Close proximity of some forest patches to each other and capture of individual mesopredators in multiple study patches indicated that some patches were not independent. Therefore, patches were considered independent only if they were $\geq$ 1.5 km apart from each other and < 10% of captured mesopredators were shared with another patch. If 2 patches were not independent, data from live-trapping and scent-station sampling efforts were combined across patches. Relative abundance data (captures/ha for live-trapping effort or RAI for scent stations) for individual species and combined species by patch (n = 15) were regressed against forest patch size (PROC REG, SAS Institute Inc. 1990). Relative abundance data also was regressed against percent forest cover and percent open habitat (Table 2) within the 500-m buffer surrounding the study patches from a reclassified Landsat TM satellite image of the area (Fig. 4). Scent-station RAIs were regressed against capture rates to examine the relationship between these measurements of abundance. All analyses using linear regression were conducted separately for raccoons and opossums and using combined data from both species. Finally, variance in capture rates and scent station RAI for 2003-2004 were tested for equality ($P < 0.05$) among large ($\geq$ 10 ha) and small ($\leq$ 10 ha) patches using t-tests (PROC TTEST; SAS Institute Inc. 1990) as a *post-hoc* test based on examination of these data across the range of patch sizes.

Multiple Regression Models.— Macrohabitat variables for each forest patch-buffer combination were entered into a stepwise multiple regression model (PROC REG; SAS Institute Inc. 1990) to select variables that were associated with capture rates and scent station RAIs within each patch. Arcsine transformation was performed on the proportions of Landsat TM land-cover types within each buffer to ensure uniformity among residuals in the analysis.

RESULTS

Live-trapping sampling efforts resulted in 2,880 trapnights. Ninety raccoons were captured 121 times, 118 opossums were captured 226 times, and 3 striped skunks were captured 4 times (Table 3). Nontarget species captured included wood rats (*Neotoma floridana*; n = 3), nine-banded armadillos (*Dasypus novemcinctus*; n = 11), and box turtles (*Terrapene ornate, T. carolina*; n = 52). Sampling efforts from scent stations resulted in 792 scent-station nights. One hundred eighty-four visits were recorded for raccoons, 302 visits were recorded for opossums and 10 visits were recorded for striped skunks. Nontarget species visits included white-tailed deer (*Odocoileus virginianus*; n = 7), cow (n = 8), rodent (n = 9) and bird (n = 16). Live-trap captures and scent station visitation were extremely low for striped skunk, so they were not included in further analyses. No animals were adversely injured during capture or handling, and no animals had to be resuscitated.

Microhabitat

Live-trap microhabitat.— Raccoons were captured at trap sites that contained more grass cover ($P < 0.05$) than unsuccessful trap sites in 2003 (Table 4). In 2004, raccoon captures occurred in traps with less coarse woody debris, decreased non-oak deciduous basal area, greater distance to a paved road, and shorter distance to the patch edge than unsuccessful traps ($P < 0.05$; Table 4). No variable differed between successful and unsuccessful traps in both years.

Opossums were captured at trap sites that were a shorter distance from a paved road than unsuccessful trap sites ($P < 0.05$; Table 5) in 2003. In 2004, opossums were captured in traps with higher cover of leaf litter cover, higher oak basal area (m^2 /ha), greater distance to an improved road, and decreased visual obstruction than unsuccessful traps ($P < 0.05$; Table 5). No variable differed between successful and unsuccessful traps for opossums in both years.

Trap sites where a raccoon or an opossum were captured had a greater aspect and decreased forb cover ($P < 0.05$; Table 6) in 2003. In 2004, raccoons and opossums were captured at trap sites with lower grass cover, greater leaf litter cover, lower moss cover, higher visual obstruction, greater oak basal area (m^2/ha), and greater distances to paved and improved roads ($P < 0.05$; Table 6). No variable differed between successful and unsuccessful captures of both mesopredators in both years.

Scent-station microhabitat.— Raccoons visited scent stations closer to the forest-patch edge ($P < 0.05$; Table 7) in 2003 than stations not visited. In 2004, scent stations with fewer stems < 5.0 cm in diameter and greater distance from a paved road ($P < 0.05$; Table 7) received more visits from raccoons. Scent stations visited by opossums had low forb cover ($P < 0.05$; Table 8) in 2003. In 2004, scent stations with more miscellaneous litter and greater distances from improved roads, all roads and the patch edge ($P < 0.05$; Table 8) received more visits from opossums. In 2003, no microhabitat variables differed between scent stations that were or were not visited by raccoons and opossums combined (Table 9). In 2004, scent stations visited by raccoons or opossums had more rock cover or greater distance to an improved road ($P < 0.05$; Table 9) than sites not visited. No variable consistently differed between visited and non-visited scent stations in 2003 and 2004.

Macrohabitat

Relative Abundance Indices.— Scent-station visitation was not correlated with capture rates in 2003 for raccoons (r^2 = 0.08, P = 0.22; Fig. 5a) and opossums (r^2 = 0.02, P = 0.60; Fig. 5b). When data for species were combined in 2003, a positive correlation (r^2 = 0.25, P = 0.02; Fig. 5c) was noted between capture rates and scent station RAI. In 2004, visits to scent stations by raccoons (P = 0.97; Fig. 6a), byopossums (P = 0.20; Fig. 6b) and by combined species (P = 0.831; Fig. 6c) were not correlated with capture rates.

Oak-forest patches that were not independent of one another (n = 7; Appendix A) were combined with nearby patches sharing mesopredator captures. Oak-forest patches # 3, 6, 12 and # 8, 10, 15, 17 were combined into single patches, respectively. Scent-station visitation was not related to capture rates in 2003 for raccoons (P = 0.13; Fig. 7a) and opossums (P = 0.969; Fig. 7b). When visitation rates of raccoons and opossums in 2003 were combined, a weak positive relationship (r^2 = 0.195, P = 0.10; Fig. 7c) existed between capture rates and scent station RAI. In 2004, visits to scent stations by raccoons (P = 0.182; Fig. 8a), opossums (P = 0.162; Fig. 8b) and combined species (P = 0.984; Fig. 8c) were not related to capture rates.

Linear Regression Models.—Relationships between species-specificrelative abundance indices and forest patch size from live trapping and scent station visitation were negative. Combined capture rates of raccoons and opossums were related negatively to patch size in 2003-2004 (r^2 = 0.324, P = 0.027; Fig. 9a). Combined scent-station visitation rates of raccoons and opossums also showed negative relationships with patch size (r^2 = 0.077, P = 0.055; Fig. 9b). I failed to reject equality of variances ($P <$ 0.05) between large and small patches relative to both live-trapping capture rate (P =

0.275) and scent station RAI (P = 0.193) in 2003-2004, indicating that these 2 measures of relative abundance were not more variable in small than large patches.

Combined capture rates for raccoons and opossums were related negatively to percent forest cover in the buffered areas around the study patches in 2003 and 2004 (r^2 = 0.085, P = 0.026; Fig. 10a). Combined scent-station visitation rates of raccoons and opossums also showed negative relationships with percent forest cover (r^2 = 0.162, P = 0.006; Fig. 10b). However, combined capture rates for raccoons and opossums were not related to percent open habitat in the buffered areas around the study patches in 2003 and 2004 (r^2 = 0.145, P = 0.394; Fig. 11a). Combined scent-station visitation rates of raccoons and opossums also showed non-significant relationships with percent open habitat (r^2 = 0.134, P = 0.206; Fig. 11b).

Multiple Regression Models.—The best-fit multiple regression model ($F_{4,18}$ = 10.6, $P < 0.001$, R^2 = 0.751; Table 10) for capture rates of raccoons in 2003 and 2004 in a forest patch was Raccoon captures = -0.54 + 297.55 (mixed forest) + 0.001 (distance to paved road) + 0.003 (distance to improved road) + 0.005 (distance to dirt road). The best-fit model predicting scent station visitation rates for raccoons ($F_{3,18}$ = 5.6, P = 0.009, R^2 = 0.528; Table 11) in 2003 and 2004 was Raccoon visits = 315.1 – 4.86 (patch size) – 2.36 (distance to other patch) – 0.15 (distance to improved road).

The best-fit multiple regression model ($F_{1,18}$ = 13.28, P = 0.002, R^2 = 0.439; Table 10) for capture rates of opossums in 2003 and 2004 in a forest patch was Opossum captures = 4.13 + 0.01 (distance to dirt road). The best-fit model predicting scent station visitation rates for opossums ($F_{2,18}$ = 4.98, P = 0.02, R^2 = 0.384; Table 11) in 2003 and

2004 was Opossum visits = 174.35 -757.36 (evergreen forest) + 0.22 (distance to improved road).

The best-fit multiple regression model ($F_{4,18}$ = 13.08, P = < 0.001, R^2 = 0.789; Table 10) for combined capture rates of raccoons and opossums in 2003 and 2004 in a forest patch was Combined captures = 7.71 -0.05 (patch size) + 180.17 (paved highway) + 0.02 (distance to any road) + 0.0004 (distance to paved road). The best-fit model ($F_{1,18}$ = 2.65, P = 0.12, R^2 = 0.135; Table 11) predicting combined scent-station visitation rates for raccoons and opossums in 2003 and 2004 was Combined visits = 300.28 + 0.64 (distance to any road).

DISCUSSION

The key finding of my research relative to the first objective was the negative relationship between both measurements of mesopredator relative abundance and oak-forest patch size. However, when RAIs from scent stations were compared with live-trapping capture rates, the 2 indices were not consistently correlated. This result suggests that the 2 indices of mesopredator relative abundance may provide different information.

Microhabitat

Microhabitat variables in the study area were ineffective predictors of mesopredator occurrence at both scent stations and live traps. No individual variable differed between successful or unsuccessful sampling sites in both years. For instance, grass was a significant predictor of raccoon captures at live traps in 2003 but not in 2004. These results were consistent with previous literature that reported no microhabitat selection when sampling mesopredators in deciduous forest habitats (Kissell and Kennedy 1992). Distance to patch edge had inconsistent effects in both live traps and scent stations in my study. Many of the patches were so small that functionally they were composed entirely of edge. Effects of edge cannot be found without some type of interior area within a patch. Other studies that have found significant vegetation variables at the microhabitat scale sampled mesopredators across multiple habitat types and found that mesopredators often occurred at sites associated with some type of forest component (Pedlar et al. 1997, Ginger et al. 2003, Baldwin et al. 2004). For example, Ginger et al. (2003) found that opossums preferred microhabitat variables associated with deciduous forest over those associated with grassland.

The ability for mesopredators to find preferred microhabitat may be constrained by the surrounding macrohabitat. Studies involving small mammals have found that large-scale habitat features can affect their spatial distribution (Foster and Gaines 1991, Manson 1999). Jorgensen and Demarais (1999) found that macrohabitat variables were better at predicting captures of small mammals than variables at the microhabitat level. Lack of variability of microhabitats within preferred macrohabitat may prevent the differentiation of preferred and non-preferred habitat variables at individual trap locations. By restricting my analysis to oak patches, I likely reduced the power to detect significant selection of microhabitat variables.

Measuring habitat use of mesopredators at the microhabitat level within only 1 habitat type does not take into account the heterogeneous landscape often contained within the home range of an individual. To accurately assess habitat utilization by mesopredators, researchers must look beyond variables in the microhabitat and determine associations of species occurrence within the entire landscape, especially in highly fragmented landscapes such as CTER.

Macrohabitat

Relative Abundance Indices.—My findings provide evidence thatmethods of measuring relative abundance are not always correlated with one another, which may reduce their efficacy as population monitors. Any measurement of relative abundance is merely an index of a true population size. Relative abundance indices can over- or under-estimate the total number of animals in a population because they assume that the sampled proportion of the population is constant (Slade and Blair 2000). Catch-per-unit effort is a time-honored measurement of relative abundance (Clark 1972, Knowlton 1972). However, recent research has suggested that it should only be used to make valid inferences concerning population size when restrictive conditions are met (Slade and Blair 2000), including counting over long periods of time for a single species and spanning a wide range of densities at a single site while using a consistent trapping protocol. Schauster et al. (2002) compared 6 methods of measuring relative abundance in kit fox and found that catch per unit effort indices ranked fifth in correctly predicting swift fox density. The best predictor of swift fox density in their study involved a combination of scent-station RAIs and mark-recapture efforts.

Use of scent stations to index mesopredator densities has seen considerable debate within the scientific literature (Minser 1984, Conner 1984). Debate has focused on lack of discrimination between individuals within a species (Heske 1995), seasonal variation in visitation rates within a species (Conner et al. 1983, Nottingham et al. 1989), and species wariness to substrates and attractants (Linhart and Knowlton 1975). Other factors such as weather play an important role in scent-station performance (Gese 2001). Attempts to differentiate among individuals within a species have led previous studies to use toe clipping to identify individual tracks (Smith et al. 1994). I addressed several of these concerns in my sampling design. Toe clipping was not used in our study to guard against negative impacts of toe-clipping on foraging behavior. By conducting both methods during the same time of year, I eliminated seasonal variation between sampling efforts. Summer is an optimal time of year for sampling mesopredators with scent stations (Leberg and Kennedy 1987). The attractant and substrate used in the study were used in preliminary trials to ensure species use. To minimize influences of weather on scent-station performance, scent stations were only run during times when the local forecast predicted $\leq$ 20% chance of rain.

Visitation rates of raccoons or opossums were not highly correlated with live-trap capture rates in 2003 or 2004. That result was not surprising given the nature of these 2 indices. Traps only capture 1 individual/night, whereas scent stations can receive a variable number of visits by a variable number of individuals. The noise associated with multiple visits likely reduces the correlation with trapping success rates. Slade and Blair (2000) found that counts of individual small mammals (such as by live trapping) were proportional to total abundance and thus effective indices of population size. However, they warned that variability in probability of capture due to site, protocol, and seasonality needs to be considered in count-abundance relationships. I controlled these factors by sampling only in oak-forest patches, using the same trapping protocol at all sites and only trapping from May to July.

Assuming thatca pture rates were better estimates of population abundance than scent-station visitation, my results were consistent with the relationship of visitation rates of raccoons to scent stations and raccoon density estimates in Tennessee (Nottingham et al. 1989, Smith et al. 1994). Both studies found that rates of raccoon visitation were not correlated with known population densities. However, other studies have found scent stations were useful in monitoring broad trends in raccoon abundance when compared to density estimates (Linscombe et al. 1983, Leberg and Kennedy 1987).

Recent research suggests thats cent stations may be more effective for estimating abundance when species occur at low densities (Warrick and Harris 2001, Schauster et al. 2002). Under low-density conditions, multiple visits to the same station from different individuals are less likely. Densities of raccoons (8.6-15.3 animals/km^2) and opossums (3.9-12.8 animals/km^2) on CTER (Kasparian et al. 2004) are considerably higher than swift fox (0.2 foxes/km^2) in Colorado (Schauster et al. 2002). Sampling densities also were considerably different between the 2 studies. Schauster et al. (2002) placed scent stations at 0.5-km intervals along 10-km survey routes, whereas I sampled scent stations 100-m apart with densities of 0.25 to 0.50/ha in each forest patch. High densities of mesopredators and scent stations within my study area may have negatively impacted scent-station RAI validity during the study because of the reason discussed above (multiple visits by multiple individuals within a single night).

An additional factor that may have played a role in scent-station visitation rates is small sample size. Sargeant et al. (2003) reported that relative abundance indices provided by scent stations increase in accuracy as the number of stations increases. I suggest that future research consider long-term studies with larger sample sizes when evaluating scent station indices as measurements of mesopredator relative abundance.

Linear Regression Models.—Previous studies have attempted to explain why mesopredator abundance seems to increase in fragmented habitats. Four hypotheses include: (1) presence of mesopredators may increase near edges due to high prey density (Ratti and Reese 1988); (2) predator density may be greater near edges than in forest interiors (Angelstam 1986, Pedlar et al. 1997); (3) the predator community may be richer in species along edges than forest interiors due to increased biodiversity (Temple and Cary 1988, Marini et al. 1995); and (4) predators may forage along travel lanes such as edges (Yahner and Wright 1985, Small and Hunter 1988, Marini et al. 1995). These studies both support and refute hypotheses concerning increased predation rates near habitat edges but due to inconsistencies within their experimental designs, clear inferences cannot be made (Paton 1994).

Results from my study show that combined mesopredator capture rates in 2003-2004 were negatively related to oak-forest patch size. My results provide indirect evidence in support of hypothesis 2 that predator density may be greater near edges than in forest interiors. In my study, mesopredators were captured at higher rates and visited scent stations at higher rates in smaller patches of forest. As patch size decreases, the ratio of forest edge to interior increases, therefore providing any possible effects from edge to occur (Barrett et al. 1995). These effects may include increases in primary productivity (Matlack 1993), increased nest predation rates (Gates and Gysel 1978, Wilcove 1985), and predator activity (Heske 1999). However, other studies have found no effect of edge on mesopredator abundance (Heske 1995, Marini et al. 1995, Chalfoun et al. 2002). Each of these latter studies tested edge effects along borders of large contiguous forest patches. The decreased level of fragmentation within these study areas when compared to mine may be the reason for differences in our results.

My results regarding the relationship of mesopredator abundance to forest patch size supportsresearch concerning predation rates on nesting birds within fragmented habitats (Wilcove 1985, Hoover et al. 1995, Donovan et al. 1997). Hoover et al. (1995) found that as forest patch size increased, so did wood thrush nesting success. Predation levels and visitation rates of mammalian predators at scent posts within these forest patches increased as patch size decreased, similar to my results. Wilcove (1985) conducted research on nest predation within 11 forest patches (3.8-905 ha) in Maryland and southeastern Tennessee. He found that nest predation was higher in smaller forest patches. Donovan et al. (1997) determined that nest predation rates (raccoons and opossums accounted for 38% of all nest predation) relative to habitat edge was high in the interior and edge of highly fragmented forests, low in the interior but high within edges of moderately fragmented forests, and low in the interior and along edges of contiguous forests. From those data, Donovan et al. (1997) concluded that predation rates of forest-nesting birds increased with increased fragmentation. These studies found evidence of increased habitat fragmentation contributing to increases in predator activity and/or nest predation rates. I predict that habitat fragmentation resulting from decreased forest patch size positively influences nest predation rates within my study area. This prediction is consistent with data in my study area (J. D. Rader, Wentz Scholarship Final Report) that demonstrated survival of artificial nests placed at a density of 1.8 nests/ha decreased from 29.5% in large patches (> 12 ha) to 26.4% in medium patches (4 – 12 ha), and 20.1% in small patches (< 4 ha). However, it should be noted that predator identity in the Rader study was not determined.

Multiple Regression Models.—Previous studies have found that mesopredator abundance was related to landscape variables such as latitude, stream density (Dijak and Thompson 2000), and fence rows (Pedlar et al. 1997). These studies found that different variables related to mesopredator abundance, suggesting that these relationships may be restricted to local study sites and cannot be generalized to other regions. This idea is supported by Sonenshine and Winslow (1972), who found that 2 populations of raccoons demonstrated different foraging behaviors based on local food sources. One group of raccoons foraged along shorelines where they preyed upon aquatic insects; the other group foraged in inland habitats with agricultural areas.

The main landscape features associated with mesopredator abundance in my study were distances to roads from trap sites within the area. Dirt, gravel (improved), and paved roads were represented separately and combined within the analysis. Increased distances from all 3 types of roads were found to be predictors of increasingraccoon capture rates, with only dirt roads being associated with opossum capture rates. Scent stations closer to gravel roads had more raccoon visits, whereas no roads of any type were associated with opossum visits. Distance to roads may provide information concerning some index of isolation from other landscape features, a variable not evaluated in my study. Smaller forest patches seemed more isolated (Fig. 4) and increased capture and visitation rates in these patches (as previously mentioned) allowed distance to roads to appear significant when determining relative abundance of mesopredators on CTER.

My overall conclusion is that mesopredators were more abundant within smaller patches of oak forest. Other studies have reported that mesopredator activity levels increased in fragmented landscapes, but no single landscape variable other than some index of fragmentation can be consistently associated with levels of mesopredator abundance. Future studies should measure the degree of fragmentation across multiple areas and then explain at what point mesopredator activity or abundance is affectedThis result may provide information concerning a threshold at which forest fragmentation can be managed to reduce predation threats on species nesting within these habitats.

LITERATURE CITED

Andren, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. Oikos 71:355-366.

Angelstam, P. 1986. Predation on ground-nesting birds' nests in relation to predator densities and habitat edge. Oikos 47:365-373.

Baldwin, R. A., A. E. Houston, M.L. Kennedy, and P.S. Liu. 2004. An assessment of microhabitat variables and capture success of striped skunks (*Mephitis mephitis*). Journal of Mammalogy 85:1068-1076.

Barrett, G. W., J. D. Peles, and S. J. Harper. 1995. Reflections on the use of experimental landscapes in mammalian ecology. Pages 157-174 *in* W. Z. Lidicker, Jr. editor. Landscape approaches in mammalian ecology and conservation. University of Minnesota Press, Minneapolis, Minnesota, USA.

Bonham, C. D. 1989. Measurements for terrestrial vegetation. John Wiley and Sons, New York, New York, USA.

Chalfoun, A. D., M. J. Ratnaswamy, and F. R. Thompson III. 2002. Songbird nest predators in forest-pasture edge and forest interior in a fragmented landscape. Ecological Applications 12:858-867.

Clark, F.W. 1972. Influence of jackrabbit density on coyote population change. Journal of Wildlife Management 36:343-356.

Conner, M. C. 1984. Response to comment on scent station indices. Wildlife Society Bulletin 12:329.

___________, R. F. Labisky, and D. R. Progulske, Jr. 1983. Scent-station indices as measures of population abundance for bobcats, raccoons, gray foxes, and opossums. Wildlife Society Bulletin 11:146-152.

Cypher, B.L., G.D. Warrick, M.R.M. Otten, T.P. O'Farrell, W.H. Berry, C.E. Harris, T.T. Kato, P.M. McCue, J.H.Scrivner, and B.W. Zoellick. 2000. Population dynamics of San Joaquin kit foxes at the Naval Petroleum Reserves in California. Wildlife Monograph 145.

Dijak, W. D., and F. R. Thompson. 2000. Landscape and edge effects on the distribution of mammalian predators in Missouri. Journal of Wildlife Management 64:209-216.

Donovan, T. M., F. R. Thompson, P. W. Jones, E.M. Annand, and F. R. Thompson, III. 1997. Variation in local-scale edge effects: mechanisms and landscape context. Ecology 78:2064-2075.

___________, F.R. Thompson, III, J.Faaborg, and J.Probst. 1995. Reproductive success of neotropical migrant birds in habitat sources and sinks. Conservation Biology 8: 1380-1395.

Dunn, E. 1977. Predation by weasels *Mustela nivalis* on breeding tits *Parus spp.* in relation to the density of tits and rodents. Journal of Animal Ecology 46: 633-652.

Engle, D. M., J. F. Stritzke, and F.T. McCollum. 1991. Vegetation management in the Cross Timbers: response of understory vegetation to herbicides and burning. Weed Technology 5:406-410.

___________, T.G. Bidwell, and R.E. Masters. 1996. Restoring cross timbers ecosystems with fire. Transactions of the North American Wildlife and

Natural Resources Conference 61: 190-199.

Ewing, J. H., J. F. Stritzke, and J. Kulbeth. 1984. Vegetation of the Cross Timbers Experimental Range, Payne County, Oklahoma. Oklahoma Agricultural Experimental Station Research Report P-856, Stillwater, Oklahoma, USA.

Foster, J. and M.S. Gaines. 1991. The effects of a successional habitat mosaic on a small mammal community. Ecology 72:1358-1373

Gardner, A. L. and M.E. Sunquist. 2003. Opossum (*Didelphis virginiana*). Pages 3-29 *in* G. A. Feldhamer, B. C. Thompson and J. A. Chapman, editors. Wild mammals of North America: biology, management, and conservation. John Hopkins University Press, Baltimore, Maryland, USA

Gates, J. E. and L.W. Gysel. 1978. Avian nest dispersion and fledgling success in field-forest ecotones. Ecology 59:871-883.

Gehrt, S. D. 2003. Raccoon (*Procyon lotor*) and allies. Pages 611- 634 *in* G.A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild mammals of North America: biology, management, and conservation. John Hopkins University Press, Baltimore, Maryland, USA.

Gese, E. M. 2001. Monitoring of terrestrial carnivore populations. Pages 372-396 *in* J. L. Gittleman, S. M.Funk, D. W. Macdonald, and R. K. Wayne, editors. Carnivore Conservation. Cambridge University, London, United Kingdom.

Ginger, S. M., E. C. Hellgren, M. A. Kasparian, L. P. Levesque, D. M. Engle, and D. M. Leslie, Jr. 2003. Niche shift by Virginia opossum following reduction of a putative competitor, the raccoon. Journal of Mammalogy 84:1279-1291.

Godin, A. J. 1982. Striped and hooded skunks (*Mephitis mephitis* and allies). Pages 674-

687 *in* J. A. Chapman and G. A. Feldhamer, editors. Wild mammals of North America: biology, management, and economics. John Hopkins University Press, Baltimore, Maryland, USA.

Heske, E. J. 1995. Mammalian abundance on forest-farm edges versus forest interiors in southern Illinois: Is there an edge effect? Journal of Mammalogy 76:562-568.

___________, S. K. Robinson, and J. D. Brawn. 1999. Predator activity and predation along songbird nests on forest-field edges in east-central Illinois. Landscape Ecology 14:345-354.

Hoover, J. P., M. C. Brittingham, and L.J. Goodrich. 1995. Effects of forest patch size on nesting success of Wood Thrushes. Auk 112:146-155.

Humphrey, S. R., and T. L. Zinn. 1982. Seasonal habitat use by river otters and everglades mink in Florida. Journal of Wildlife Management 46:375-381.

Jorgensen, E. E. and S. Demamarais. 1999. Spatial scale dependence of rodent habitat use. Journal of Mammalogy 80: 421-429.

Kasparian, M. A., E. C. Hellgren, S. M. Ginger, L. P. Levesque, J. E. Clark, D. L. Winkelman, and D. M. Engle. 2004. Population characteristics of Virginia opossum in the cross timbers during raccoon reduction. American Midland Naturalist 151:154-163.

Kaufmann, J. 1982. Raccoons and allies. Pages 567-585 *in* J. A. Chapman and G. A. Feldhamer, editors. Wild mammals of North America: biology, management, and economics. John Hopkins University Press, Baltimore, Maryland, USA.

Kissell, Jr, R. E., and M. L. Kennedy. 1992. Ecological relationships of co-ocurring populations of opossums (*Didelphis viginiana*) and raccoons (*Procyon lotor*) in

Tennessee. Journal of Mammalogy 73:808-813.

Knowlton, F. F. 1972. Preliminary interpretations of coyote population mechanics with some management implications. Journal of Wildlife Management 36:369-382.

Kuehl, A. K. and W. R. Clark. 2002. Predator activity related to landscape features in northern Iowa. Journal of Wildlife Management 66:1224-1234.

Lancia, R. A., J. D. Nichols, and K. H. Pollock. 1994. Estimating the number of animals in wildlife populations. Pages 215-253 *in* T.A. Bookhout, editor. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Maryland, USA.

Leberg, P. L., and M. L. Kennedy. 1987. Use of scent station methodology to assess raccoon abundance. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 41:394-403.

Levesque, L. P. 2001. Effect of land-use manipulations on habitat associations and demography of mesopredators in the crosstimbers ecoregion of Oklahoma. M. S. Thesis, Oklahoma State University, Stillwater, Oklahoma.

Linscombe, G., N. Kinler, and V. Wright. 1983. An analysis of scent station response in Louisiana. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 37: 190-200.

Linhart, S. B., and F. F. Knowlton. 1975. Determining relative abundance of coyotes by scent station lines. Wildlife Society Bulletin 3:119-124.

Marini, M. A., S. K. Robinson, and E. J. Heske. 1995. Edge effects on nest predation in the Shawnee National Forest, southern Illinois. Biological Conservation 74:203-213.

Martin, T. E. 1993. Nest predation and nest sites; new perspectives on old patterns. Bioscience 43:523-532.

Matlack, G. R. 1993. Microenvironment variation within and among forest edge sites in the eastern United States. Biological Conservation 66:185-194.

Matthiae, P. E., and F. Stearns. 1981. Mammals in forest islands in southeastern Wisconsin. Pages 55-66 *in* R. L. Burgess and D. M. Sharpe, editors. Forest island dynamics in man-dominated landscapes. Springer-Verlag, New York, NewYork,USA.

Minser, W. G., III. 1984. Comments on scent-station method for monitoring furbearers. Wildlife Society Bulletin 12:328.

Nottingham, B. G., Jr., K. G. Johnson, and M. R. Pelton. 1989. Evaluation of scent-station surveys to monitor raccoon density. Wildlife Society Bulletin 17:29-35.

Odum, E. P. and G. W. Barrett. 2005. Fundamentals of Ecology, Fifth edition. Thompson Brooks/Cole, Belmont CA, USA.

Oehler, J. D. and J. A. Litvaitis. 1996 The role of spatial scale in understanding responses of medium-sized carnivores to forest fragmentation. Canadian Journal of Zoology 74:2070-2079.

Page, G. W., L. E. Stenzel, D. W. Winkler, and C. W. Swarth. 1983. Spacing out at Mono Lake: breeding success, nest density, and predation in the snowy plover. Auk 100: 13-24.

Paton, P. W. C. 1994. The edge effect on avian nest success: how strong is the evidence? Conservation Biology 8: 17-26.

Pedlar, J. H., L. Fahrig, and H. G. Merriam. 1997. Raccoon habitat use at 2 spatial scales. Journal of Wildlife Management 61:102-112.

Pimlott, D. H., J. A. Shannon, and G.B. Kolenowsky. 1969. The ecology of the timber wolf in Algonquin Provincial Park. Ontario Department of Lands and Forestry. Research Branch Research Report (Wildlife) Number 87. Ontario, Canada.

Ratti, J. T., and K. P. Reese. 1988. Preliminary test of the ecological trap hypothesis. Journal of Wildlife Management 52: 484-491.

Robinson, S. K., F. R. Thompson, III, T. M. Donovan, D. R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267: 1987-1990.

Rogers, C. M, and M. J. Caro. 1998. Song sparrows, top carnivores and nest predation: a test of the mesopredator release hypothesis. Oecologia 116:227-233.

Rosatte, R.C. 1987. Striped, spotted, hooded, and hog-nosed skunks. Pages 598-613 *in* Novak, M., J.A. Baker, M.E. Obbard, and B. Malloch, editors. Wild furbearer management and conservation in North America. Ontario Trappers Association, Ontario, Canada.

Roughton, R. D., and M. W. Sweeny. 1982. Refinements in scent-station methodology for assessing trends in carnivore populations. Journal of Wildlife Management 46: 217-229.

Sanderson, G. C. 1987. Raccoon. Pages 486-499 *in* Novak, M, J.A. Baker, M.E. Obbard, and B. Malloch, editors. Wild furbearer management and conservation in North America. Ontario Trappers Association, Ontario, Canada.

Sargeant, G. A., D. H. Johnson, and W. E. Berg. 1998. Interpreting carnivore scent-station surveys. Journal of Wildlife Management 62:1235-1245.

__________, __________, and ___________. 2003. Sampling designs for carnivore scent-station surveys. Journal of Wildlife Management 67: 289-298.

Seidensticker, J., M. A. O'Connell, and A. J. T. Johnsingh. 1987. Virginia opossum. Pages 246-261 *in* Novak, M, J.A. Baker, M.E. Obbard, and B. Malloch, editors. Wild furbearer management and conservation in North America. Ontario Trappers Association, Ontario, Canada.

Schauster, E. R., E. M. Gese, and A. M. Kitchen. 2002. An evaluation of survey methods for monitoring swift fox abundance. Wildlife Society Bulletin 30: 464-477.

Shirer, H. W., and H. S. Fitch. 1970. Comparison from radiotracking of movements and denning habits of the raccoon, striped skunk, and opossum in northeastern Kansas. Journal of Mammalogy 51:491-503.

Slade, N.A. and S.M. Blair. 2000. An empirical test of using counts of individuals captured as indices of population size. Journal of Mammalogy 81:1035-1045.

Small, M. F., and M. L. Hunter. 1988. Forest fragmentation and avian nest predation in forested landscapes. Oecologia 76:62-64.

Smith, W. P., D. L. Borden, and K. M. Endres. 1994. Scent station visits as an index to abundance of raccoons: an experimental manipulation. Journal of Mammalogy 75:637-647.

Sonenshine, D. E. and E. L. Winslow. 1972. Contrasts in distribution of raccoons in two Virginia localities. Journal of Wildlife Management 36:839-847.

Sovada, M. A., M. C. Zicus, R. J. Greenwood, D. P. Rave, W. E. Newton, R. O. Woodward, and J. A. Beiser. 2000. Relationships of habitat patch size to predator community and survival of duck nests. Journal of Wildlife Management 64:820-831.

Stritzke, J. F., D. M. Engle, and F. T. McCollum. 1991. Vegetative management in the Cross Timbers: Response of woody species to herbicides and burning. Weed Technology 5:400-405.

Sumner, P. W., and E. P. Hill. 1980. Scent stations as indices of abundance in some furbearers of Alabama. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 34:572-583

Temple, S. A, and J. R. Cary. 1988. Modeling dynamics of habitat-interior bird populations in fragmented landscapes. Conservation Biology 2:340-347.

Vickery, P.D., M. L. Hunter Jr., and J.V. Wells. 1992. Evidence of incidental nest predation and its effects on nests of threatened grassland birds. Oikos 63:281-288.

Warrick, G.D. and C. E. Haris. 2001. Evaluation of spotlight and scent-station surveys to monitor kit fox abundance. Wildlife Society Bulletin 29:827-832.

Wilcove, D. S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology 66:1211-1214.

Winter, M., D. H. Johnson, and J. Faaborg. 2000. Evidence for edge effects on multiple levels in tallgrass prairie. Condor 102:256-266.

Wood, J. E. 1959. Relative estimates of fox population levels. Journal of Wildlife Management 23:53-63.

Yahner, R. H. 1988. Changes in wildlife communities near edges. Conservation Biology 2:333-339.

___________, and A. L. Wright . 1985. Depredation of artificial ground nests. Journal of Wildlife Management 49:508-513.

___________, and D. P. Scott. 1988. Effects of forest fragmentation on depredation of artificial nests. Journal of Wildlife Management 52:158-161.

Zegers, D. A., S. May, and L. J. Goodrich. 2000. Identification of nest predators at farm/forest edge and interior sites. Journal of Field Ornithology 71:207-216.

Table 1. Descriptions of all macrohabitat variables for Cross Timbers Experimental Range, Payne County Oklahoma.

Variable Name	**Description**
Patch Size	Oak forest patch size in hectares
Grassland	Grasslands/Herbaceous - Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is < 25 %, but exceeds the combined cover of the woody species present.These areas are not subject to intensive management, but they are often utilized for grazing.
Open Water	Open Water - areas of open water, generally with < 25 % cover of water (per pixel).
Commercial	Includes infrastructure (e.g. roads, railroads, etc.) and all highways and all developed areas not classified as High Intensity Residential.
Deciduous Forest	Areas dominated by trees where $\geq$ 75 % of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen Forest	Areas characterized by trees where $\geq$ 75 % of the tree species maintain their leaves all year. Canopy is never without green foliage.
Mixed Forest	Areas dominated by trees where neither deciduous nor evergreen species represent > 75 % of the cover present.
Shrubland	Areas characterized by natural or semi-natural woody vegetation with aerial stems, generally less than 6 meters tall with individuals or clumps not touching to interlocking. Both evergreen and deciduous species of true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions are included.
Pasture	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.
Row Crops	Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.
Small Grains	Areas used for the production of graminoid crops such as wheat, barley, oats, and rice

Table 1. continued

Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for 75-100 % of the cover and the soil or substrate is periodically saturated with or covered with water.
Edge to Interior Ratio	Forest patch perimeter divided by total patch area
Distance to Other Patch	Distance to nearest forest patch in meters
Distance to Any Road	Distance to any nearest road in meters
Distance to Paved Road	Distance to nearest paved road in meters
Distance to Improved Road	Distance to nearest gravel road in meters
Distance to Dirt Road	Distance to nearest dirt road in meters

Table 2. Descriptions of macrohabitat variables from the reclassified Landsat TM Image of Cross Crosstimbers Experimental Range, Payne County, Oklahoma.

Variable	Description
Forest Cover	Forest cover refers to any type of tree cover found in the Landsat TM Image
	Variables combined to create Forest Cover include:
	Deciduous Forest
	Evergreen Forest
	Mixed Forest
Open Habitat	Open habitat refers to any non woody, herbaceous cover in the Landsat TM Image
	Variables combined to create Open Habitat include:
	Grassland
	Pasture
	Row Crops
	Small Grains

Table 3: Raccoon, opossum, and striped skunk; unique and total captures, visits to scent stations and numbers of individuals ear tagged in 2003 and 2004 on Cross Timbers Experimental Range, Payne County, Oklahoma.

		Raccoon			Virginia Opossum			Skunk		
Year	session[1]	Individuals captured[2]	Total Captures	Scent-station visits	Individuals captured[2]	Total Captures	Scent-station visits	Individuals captured[2]	Total Captures	Scent-station visits
2003	1	40	45	23	46	79	21	2	3	0
	2	23	24	22	39	67	19	0	0	3
2004	1	22	26	33	19	26	43	1	1	1
	2	24	26	14	36	54	68	0	0	1

[1]2003: session 1 = 31 May - 28 June; session 2 = 4 July - 29 July

[1]2004 session 1 = 2 May - 23 May; session 2 = 23 June - 11 August

[2]Individuals captured in >1 session were tallied in each session captured.

Table 4. Microhabitat variables at successful (n = 37 in 2003, n = 35 in 2004) and unsuccessful (n = 35 in 2003, n = 37 in 2004) trapsites for raccoons on Cross Timbers Experimental Range, Payne County, Oklahoma.

		Successful		Unsuccessful				
Variable	Year	Mean	SE	Mean	SE	t	df	P >|t|
Aspect (°)	2003	139.16	14.20	166.86	16.44	1.28	70	0.205
	2004	160.43	15.80	136.92	13.97	-1.12	70	0.268
Coarse Woody Debris (# logs)	2003	10.16	1.39	9.89	1.24	-0.15	70	0.883
	2004	8.11	0.79	11.73	1.61	2.02	52.2	0.049
Forb Cover (%)	2003	2.26	1.01	1.09	0.54	-1.02	54.9	0.312
	2004	2.17	1.07	3.62	1.39	0.82	70	0.415
Grass Cover (%)	2003	11.04	2.13	5.54	1.59	-2.05	70	0.044
	2004	9.73	2.23	12.76	2.67	0.87	70	0.390
Woody Cover (%)	2003	10.89	2.32	9.29	1.91	-0.53	70	0.596
	2004	22.23	2.69	25.00	3.30	0.65	70	0.520
Bare Ground (%)	2003	6.26	1.67	5.51	1.28	-0.35	70	0.727
	2004	3.80	1.10	4.43	1.08	0.41	70	0.684
Moss (%)	2003	0.14	0.08	0.36	0.24	0.87	42.0	0.391
	2004	0.74	0.40	0.35	0.16	-0.92	45.2	0.365
Rock (%)	2003	0.11	0.10	0.23	0.21	0.51	47.0	0.610
	2004	0.53	0.31	1.54	1.06	0.92	42.0	0.364
Leaf Litter (%)	2003	52.34	4.00	60.29	3.15	1.55	70	0.126
	2004	45.01	3.60	41.50	3.32	-0.72	70	0.475
Other Litter (%)	2003	5.51	1.02	6.77	1.46	0.72	70	0.477
	2004	7.76	1.36	9.16	0.91	0.86	59.9	0.395
Visual Obstruction (%)	2003	34.46	0.03	34.00	0.03	-0.11	70	0.914
	2004	43.93	0.03	43.51	0.03	-0.1	70	0.921

Table 4. continued

Overhead Density (%)	2003	67.89	0.03	73.51	0.03	1.41	70	0.163
	2004	68.79	0.03	74.32	0.03	1.29	70	0.200
Stems <5.0 cm (stems/ ha)	2003	23949	2197	25343	25820	0.41	70	0.681
	2004	27182	2607	25713	2075	-0.44	70	0.659
Cedar basal area (m^2 / ha)	2003	0.04	0.01	0.06	0.02	0.93	50.1	0.357
	2004	0.06	0.02	0.03	0.01	-1.71	46.8	0.094
Non Oak basal area (m^2 / ha)	2003	0.09	0.02	0.07	0.02	-0.54	70	0.591
	2004	0.05	0.01	0.11	0.03	2.07	44.0	0.044
Oak basal area (m^2 / ha)	2003	0.42	0.04	0.51	0.04	1.54	70	0.129
	2004	0.53	0.04	0.44	0.04	-1.49	70	0.141
Distance to Paved Road (m)	2003	2056	335.59	2059	293.31	0.01	70	0.994
	2004	2845	357.22	1313	209.19	-3.75	70	0.000
Distance to Improved Road (m)	2003	449.07	52.36	496.53	52.95	0.64	70	0.526
	2004	489.76	50.86	455.48	54.32	-0.46	70	0.647
Distance to Dirt Road (m)	2003	234.66	23.66	240.32	28.51	0.15	70	0.879
	2004	207.95	25.27	265.28	25.91	1.58	70	0.118
Distance to Any Road (m)	2003	161.22	16.61	174.84	20.35	0.52	70	0.604
	2004	166.19	21.55	169.40	15.28	0.12	70	0.903
Distance to Patch Edge (m)	2003	70.70	14.40	77.96	11.60	0.39	70	0.698
	2004	48.31	6.86	98.75	15.87	2.92	48.9	0.005

Table 5. Microhabitat variables at successful (n = 61 in 2003, n = 45 in 2004) and unsuccessful (n = 11 in 2003, n = 27 in 2004) trapsites for opossums on Cross Timbers Experimental Range, Payne County, Oklahoma.

		Successful		Unsuccessful				
Variable	Year	Mean	SE	Mean	SE	t	df	P>|t|
Aspect (°)	2003	148.64	11.50	174.73	32.19	0.86	70	0.392
	2004	132.51	12.78	174.74	17.44	1.98	70	0.052
Coarse Woody Debris (# logs)	2003	9.80	1.01	11.27	2.36	0.57	70	0.572
	2004	9.89	1.14	10.11	1.62	0.11	70	0.909
Forb Cover (%)	2003	1.85	0.67	0.77	0.72	-1.09	31.0	0.284
	2004	3.41	1.33	2.09	0.77	-0.85	66.0	0.396
Grass Cover (%)	2003	8.30	1.52	8.73	3.25	0.11	70	0.912
	2004	8.48	1.84	15.96	3.37	1.95	41.6	0.058
Woody Cover (%)	2003	9.89	1.70	11.32	2.85	0.34	70	0.735
	2004	23.68	2.76	23.61	3.42	-0.02	70	0.988
Bare Ground (%)	2003	6.31	1.17	3.59	2.41	-0.93	70	0.357
	2004	3.86	0.86	4.57	1.49	0.45	70	0.654
Moss (%)	2003	0.29	0.15	0.00	0.00	-1.95	60.0	0.056
	2004	0.72	0.32	0.24	0.15	-1.35	61.2	0.181
Rock (%)	2003	0.20	0.13	0.00	0.00	-1.46	60.0	0.150
	2004	1.17	0.86	0.85	0.46	-0.32	63.9	0.749
Leaf Litter (%)	2003	54.92	2.90	63.32	5.07	1.17	70	0.246
	2004	47.37	3.04	36.28	3.77	-2.27	70	0.026
Other Litter (%)	2003	6.06	0.91	6.50	2.86	0.18	70	0.857
	2004	8.68	0.99	8.15	1.41	-0.31	70	0.754
Visual Obstruction (%)	2003	34.02	0.02	35.45	0.06	0.25	70	0.807
	2004	39.50	0.03	50.74	0.03	2.75	70	0.008

Table 5. continued

Overhead Density (%)	2003	70.42	0.02	71.78	0.05	0.24	70	0.808
	2004	73.91	0.03	67.83	0.04	-1.38	70	0.172
Stems <5.0 cm (stems/ ha)	2003	24709	1870	24170	3816	-0.11	70	0.909
	2004	27380	2101	24837	2672	-0.75	70	0.459
Cedar basal area (m^2 / ha)	2003	0.05	0.01	0.05	0.02	0.21	70	0.837
	2004	0.03	0.01	0.05	0.02	0.97	31.9	0.337
Non Oak basal area (m^2 / ha)	2003	0.09	0.02	0.05	0.01	-1.95	55.1	0.057
	2004	0.07	0.02	0.09	0.03	0.63	70	0.531
Oak basal area (m^2 / ha)	2003	0.45	0.03	0.54	0.05	1.08	70	0.282
	2004	0.53	0.04	0.41	0.05	-2.03	70	0.046
Distance to Paved Road (m)	2003	1803.08	222.66	3471.54	639.56	2.83	70	0.006
	2004	1756.15	256.56	2561.03	397.87	1.78	70	0.079
Distance to Improved Road (m)	2003	468.82	42.16	490.55	68.56	0.21	70	0.835
	2004	526.49	51.79	381.56	44.08	-2.13	69.3	0.037
Distance to Dirt Road (m)	2003	248.66	20.51	175.06	33.49	-1.46	70	0.149
	2004	240.87	24.97	231.65	26.09	-0.24	70	0.810
Distance to Any Road (m)	2003	170.57	14.14	152.71	34.24	-0.49	70	0.625
	2004	163.47	15.11	175.12	24.14	0.43	70	0.668
Distance to Patch Edge (m)	2003	76.32	10.30	62.62	20.75	-0.53	70	0.597
	2004	71.61	9.68	78.61	18.90	0.33	39.8	0.743

Table 6. Microhabitat variables at successful (n = 67 in 2003, n = 60 in 2004) and unsuccessful (n = 5 in 2003, n = 12 in 2004) trapsites for raccoons and opossums on Cross Timbers Experimental Range, Payne County, Oklahoma.

		Successful		Unsuccessful				
Variable	Year	Mean	SE	Mean	SE	*t*	df	P>|t|
Aspect (°)	2003	146.37	10.90	236.40	45.17	2.16	70	0.034
	2004	147.57	11.58	152.25	26.45	0.16	70	0.870
Coarse Woody Debris (# logs)	2003	9.99	0.98	10.60	2.25	0.17	70	0.868
	2004	9.18	0.90	13.92	3.14	1.45	12.9	0.172
Forb Cover (%)	2003	1.81	0.62	0.00	0.00	-2.91	66.0	0.005
	2004	2.98	1.04	2.58	1.13	-0.26	32.9	0.796
Grass Cover (%)	2003	8.63	1.45	4.90	3.34	-0.69	70	0.493
	2004	8.73	1.58	24.04	5.76	2.56	12.7	0.024
Woody Cover (%)	2003	10.16	1.58	9.50	4.91	-0.11	70	0.912
	2004	23.08	2.25	26.50	6.31	0.59	70	0.554
Bare Ground (%)	2003	5.81	1.08	7.00	5.07	0.28	70	0.777
	2004	4.32	0.86	3.17	1.76	-0.56	70	0.581
Moss (%)	2003	0.26	0.13	0.00	0.00	-1.95	66.0	0.056
	2004	0.65	0.25	0.00	0.00	-2.61	59.0	0.012
Rock (%)	2003	0.18	0.12	0.00	0.00	-1.46	66.0	0.150
	2004	1.13	0.67	0.63	0.63	-0.56	40.4	0.581
Leaf Litter (%)	2003	56.04	2.75	58.40	6.09	0.23	70	0.818
	2004	45.54	2.72	31.54	4.11	-2.20	70	0.031
Other Litter (%)	2003	5.96	0.84	8.40	6.20	0.39	4.2	0.715
	2004	8.46	0.89	8.58	1.99	0.06	70	0.955
Visual Obstruction (%)	2003	34.03	0.02	37.00	0.11	0.36	70	0.721
	2004	41.17	0.02	56.46	0.05	2.90	70	0.005

Table 6. continued

Overhead Density (%)	2003	70.30	0.02	75.00	0.06	0.59	70	0.555
	2004	71.88	0.02	70.38	0.06	-0.26	70	0.797
Stems <5.0 cm (stems/ ha)	2003	24623	1732	24675	7540	0.01	70	0.994
	2004	26425	1846	26437	3690	0.00	70	0.998
Cedar basal area (m^2 / ha)	2003	0.04	0.01	0.07	0.03	0.66	70	0.511
	2004	0.04	0.01	0.02	0.01	-1.41	32.2	0.169
Non Oak basal area (m^2 / ha)	2003	0.09	0.02	0.05	0.02	-1.40	16.3	0.179
	2004	0.07	0.01	0.14	0.05	1.39	12.8	0.189
Oak basal area (m^2 / ha)	2003	0.46	0.03	0.50	0.08	0.39	70	0.697
	2004	0.51	0.03	0.35	0.08	-2.15	70	0.035
Distance to Paved Road (m)	2003	1984	229.09	3041	869.1	1.21	70	0.229
	2004	2197	256.68	1361	303.7	-2.10	29.5	0.044
Distance to Improved Road (m)	2003	471.72	39.11	477.85	114.9	0.04	70	0.967
	2004	513.43	41.77	265.72	42.51	-4.16	36.2	0.000
Distance to Dirt Road (m)	2003	241.88	19.30	177.51	48.24	-0.89	70	0.375
	2004	230.17	21.02	273.60	31.42	0.88	70	0.380
Distance to Any Road (m)	2003	167.45	13.62	173.08	46.49	0.11	70	0.913
	2004	164.53	14.27	184.39	32.47	0.57	70	0.573
Distance to Patch Edge (m)	2003	73.16	9.57	88.55	39.47	0.42	70	0.675
	2004	65.34	8.02	118.71	37.00	1.41	12.1	0.184

Table 7. Microhabitat variables at successful (n = 36 in 2003, n = 34 in 2004) and unsuccessful (n = 36 in 2003, n = 38 in 2004) scent stations for raccoons on Cross Timbers Experimental Range, Payne County, Oklahoma

		Successful		Unsuccessful				
Variable	Year	Mean	SE	Mean	SE	t	df	P>|t|
Aspect (°)	2003	147.06	16.94	153.33	14.25	0.28	70	0.778
	2004	148.06	15.35	141.89	15.30	-0.28	70	0.778
Coarse Woody Debris (# logs)	2003	9.89	1.01	10.33	1.34	0.27	70	0.791
	2004	9.03	0.97	11.37	1.30	1.44	66.6	0.154
Forb Cover (%)	2003	0.86	0.45	1.51	0.75	0.75	57.1	0.456
	2004	3.60	1.62	4.05	1.24	0.22	70	0.824
Grass Cover (%)	2003	6.53	1.92	5.11	1.44	-0.59	70	0.557
	2004	6.21	1.54	11.12	2.11	1.88	65.8	0.064
Woody Cover (%)	2003	11.24	1.75	6.90	1.44	-1.91	70	0.060
	2004	20.53	2.67	20.95	2.46	0.12	70	0.909
Bare Ground (%)	2003	6.03	1.90	4.89	1.92	-0.42	70	0.675
	2004	5.54	1.42	5.58	1.18	0.02	70	0.985
Moss (%)	2003	0.13	0.09	0.26	0.22	0.58	45.1	0.563
	2004	0.91	0.62	0.54	0.45	-0.49	70	0.626
Rock (%)	2003	0.24	0.21	0.51	0.31	0.75	61.5	0.458
	2004	0.90	0.46	1.11	0.69	0.25	63.2	0.802
Leaf Litter (%)	2003	62.36	3.63	61.21	3.24	-0.24	70	0.813
	2004	41.35	3.65	44.25	3.69	0.56	70	0.580
Other Litter (%)	2003	6.17	1.10	8.89	1.68	1.35	60.5	0.181
	2004	12.43	1.78	13.33	2.07	0.33	70	0.745
Visual Obstruction (%)	2003	0.30	0.03	0.26	0.03	-1.02	70	0.311
	2004	0.36	0.03	0.35	0.03	-0.33	70	0.741

Table 7. continued

Overhead Density (%)	2003	0.70	0.03	0.75	0.02	1.31	70	0.194
	2004	0.76	0.02	0.77	0.02	0.21	70	0.833
Stems <5.0 cm (stems/ ha)	2003	24260	1843	18871	2338	-1.81	70	0.075
	2004	20992	1616	27069	2407	2.10	63.4	0.040
Cedar basal area (m^2 / ha)	2003	0.04	0.01	0.06	0.01	0.88	61.0	0.381
	2004	0.05	0.01	0.04	0.01	-0.58	70	0.564
Non Oak basal area (m^2 / ha)	2003	0.10	0.02	0.12	0.04	0.30	55.4	0.768
	2004	0.10	0.03	0.12	0.03	0.47	70	0.643
Oak basal area (m^2 / ha)	2003	0.47	0.04	0.45	0.04	-0.39	70	0.700
	2004	0.49	0.04	0.47	0.04	-0.26	70	0.799
Distance to Paved Road (m)	2003	1969.25	328.76	2131	302.0	0.36	70	0.717
	2004	2726.03	376.62	1445	211.7	-2.96	52.5	0.005
Distance to Improved Road (m)	2003	436.65	51.99	508.98	52.64	0.98	70	0.332
	2004	474.38	45.88	471.41	57.38	-0.04	70	0.968
Distance to Dirt Road (m)	2003	246.30	29.66	226.73	26.15	-0.49	70	0.622
	2004	224.13	26.21	247.60	29.17	0.59	70	0.555
Distance to Any Road (m)	2003	161.31	20.30	175.18	17.36	0.52	70	0.605
	2004	185.27	22.72	153.02	14.72	-1.19	57.5	0.238
Distance to Patch Edge (m)	2003	50.37	6.21	126.37	28.97	2.57	38.2	0.014
	2004	97.95	30.19	79.79	11.35	-0.56	42.2	0.577

Table 8. Microhabitat variables at successful (n = 29 in 2003, n = 51 in 2004) and unsuccessful (n = 43 in 2003, n = 21 in 2004) scent stations for opossums on Cross Timbers Experimental Range, Payne County, Oklahoma.

		Successful		Unsuccessful				
Variable	Year	Mean	SE	Mean	SE	t	df	P>|t|
Aspect (°)	2003	154.79	18.21	147.09	13.88	-0.34	70	0.734
	2004	140.80	13.26	154.52	18.43	0.58	70	0.567
Coarse Woody Debris (# logs)	2003	9.86	0.94	10.28	1.25	0.27	69.6	0.790
	2004	11.06	1.11	8.33	0.83	-1.97	68.3	0.053
Forb Cover (%)	2003	0.29	0.17	1.79	0.71	2.06	46.7	0.045
	2004	3.41	1.14	4.88	2.04	0.67	70	0.508
Grass Cover (%)	2003	4.66	1.36	6.60	1.78	0.87	69.7	0.388
	2004	9.10	1.61	8.07	2.54	-0.34	70	0.733
Woody Cover (%)	2003	8.24	1.55	9.63	1.63	0.59	70	0.559
	2004	18.90	1.91	25.24	3.96	1.62	70	0.110
Bare Ground (%)	2003	5.81	1.95	5.22	1.84	-0.21	70	0.831
	2004	5.39	1.05	5.98	1.84	0.29	70	0.773
Moss (%)	2003	0.31	0.28	0.12	0.07	-0.68	31.9	0.501
	2004	0.47	0.34	1.31	1.00	0.79	24.8	0.435
Rock (%)	2003	0.55	0.37	0.26	0.19	-0.71	42.1	0.480
	2004	1.16	0.54	0.64	0.59	-0.55	70	0.582
Leaf Litter (%)	2003	62.78	4.13	61.12	2.97	-0.33	70	0.739
	2004	45.08	3.02	37.55	4.90	-1.33	70	0.188
Other Litter (%)	2003	8.53	1.69	6.85	1.26	-0.82	70	0.418
	2004	14.57	1.78	8.86	1.57	-2.41	62.9	0.019
Visual Obstruction (%)	2003	0.31	0.03	0.26	0.03	-1.21	70	0.232
	2004	0.35	0.03	0.37	0.04	0.33	70	0.739

Table 8. continued

Overhead Density (%)	2003	0.71	0.03	0.73	0.02	0.40	70	0.693
	2004	0.78	0.01	0.72	0.04	-1.55	26.8	0.132
Stems <5.0 cm (stems/ ha)	2003	21185	2218	21822	2063	0.21	70	0.838
	2004	23938	1867	24833	2600	0.27	70	0.791
Cedar basal area (m^2 / ha)	2003	0.07	0.02	0.04	0.01	-1.42	45.7	0.162
	2004	0.05	0.01	0.04	0.01	-0.47	70	0.637
Non Oak basal area (m^2 / ha)	2003	0.10	0.02	0.12	0.03	0.52	69.0	0.603
	2004	0.13	0.03	0.07	0.02	-1.62	69.4	0.109
Oak basal area (m^2 / ha)	2003	0.44	0.04	0.48	0.04	0.76	70	0.452
	2004	0.49	0.04	0.44	0.04	-0.89	70	0.374
Distance to Paved Road (m)	2003	1978	340.46	2099	295.6	0.27	70	0.791
	2004	1931	241.02	2338	490.3	0.83	70	0.408
Distance to Improved Road (m)	2003	560.10	55.29	413.94	47.87	-1.98	70	0.052
	2004	534.17	45.20	323.81	51.72	-2.70	70	0.009
Distance to Dirt Road (m)	2003	226.38	22.66	243.36	29.34	0.46	69.8	0.648
	2004	242.65	23.86	221.63	35.16	-0.48	70	0.631
Distance to Any Road (m)	2003	200.79	22.82	146.30	15.40	-1.98	52.1	0.053
	2004	183.38	17.19	131.50	16.11	-2.20	60.2	0.032
Distance to Patch Edge (m)	2003	63.71	7.62	105.00	25.05	1.58	49.5	0.121
	2004	103.25	20.98	52.23	10.76	-2.16	68.0	0.034

Table 9. Microhabitat variables at successful (n = 48 in 2003, n = 62 in 2004) and unsuccessful (n = 24 in 2003, n = 10 in 2004) scent stations for raccoons and opossums on Cross Timbers Experimental Range, Payne County, Oklahoma.

		Successful		Unsuccessful				
Variable	Year	Mean	SE	Mean	SE	t	df	P>|t|
Aspect (°)	2003	152.21	14.38	146.17	16.55	-0.26	70	0.798
	2004	149.29	11.74	117.00	26.59	-1.04	70	0.304
Coarse Woody Debris (# logs)	2003	9.56	0.85	11.21	1.83	0.82	33.4	0.420
	2004	10.42	0.95	9.30	1.17	-0.74	23.1	0.466
Forb Cover (%)	2003	0.80	0.35	1.96	1.10	1.00	27.7	0.325
	2004	3.77	1.08	4.25	2.83	0.16	70	0.871
Grass Cover (%)	2003	5.79	1.50	5.88	2.00	0.03	70	0.974
	2004	8.90	1.45	8.20	3.88	-0.18	70	0.860
Woody Cover (%)	2003	9.28	1.43	8.65	2.00	-0.26	70	0.797
	2004	20.47	1.93	22.50	5.13	0.39	70	0.699
Bare Ground (%)	2003	4.97	1.46	6.44	2.82	0.51	70	0.610
	2004	5.69	1.01	4.80	2.04	-0.33	70	0.739
Moss (%)	2003	0.26	0.18	0.06	0.03	-1.10	50.5	0.277
	2004	0.83	0.44	0.00	0.00	-1.90	61.0	0.062
Rock (%)	2003	0.34	0.23	0.44	0.33	0.24	70	0.814
	2004	1.16	0.49	0.05	0.05	-2.27	62.2	0.027
Leaf Litter (%)	2003	63.59	3.05	58.17	3.88	-1.06	70	0.293
	2004	42.02	2.80	48.25	6.83	0.83	70	0.409
Other Litter (%)	2003	7.28	1.17	8.02	1.96	0.34	70	0.733
	2004	13.27	1.56	10.60	1.81	-1.12	25.3	0.274
Visual Obstruction (%)	2003	0.30	0.02	0.25	0.04	-1.10	70	0.274
	2004	0.36	0.02	0.36	0.06	-0.02	70	0.988

Table 9. continued

Overhead Density (%)	2003	0.71	0.02	0.74	0.03	0.57	70	0.570
	2004	0.77	0.02	0.74	0.05	-0.65	70	0.519
Stems <5.0 cm (stems/ ha)	2003	21062	1662	22572	3133	0.47	70	0.641
	2004	24092	1650	24862	3988	0.17	70	0.862
Cedar basal area (m^2 / ha)	2003	0.05	0.01	0.05	0.01	-0.47	70	0.638
	2004	0.05	0.01	0.05	0.02	0.13	70	0.901
Non Oak basal area (m^2 / ha)	2003	0.09	0.02	0.15	0.06	0.94	28.2	0.356
	2004	0.12	0.03	0.11	0.04	-0.16	70	0.875
Oak basal area (m^2 / ha)	2003	0.47	0.03	0.44	0.05	-0.52	70	0.604
	2004	0.48	0.03	0.45	0.07	-0.38	70	0.708
Distance to Paved Road (m)	2003	2004	279.88	2141	367.58	0.29	70	0.774
	2004	2150	244.46	1432	484.77	-1.12	70	0.267
Distance to Improved Road (m)	2003	486.34	44.79	445.75	66.47	-0.51	70	0.608
	2004	504.97	39.72	273.41	79.17	-2.22	70	0.029
Distance to Dirt Road (m)	2003	250.39	22.79	208.76	37.53	-1.00	70	0.322
	2004	233.74	21.06	253.72	57.38	0.35	70	0.728
Distance to Any Road (m)	2003	182.72	17.46	139.31	18.29	-1.56	70	0.124
	2004	174.87	14.94	127.20	20.84	-1.25	70	0.217
Distance to Patch Edge (m)	2003	60.01	6.23	145.09	42.70	1.97	24.0	0.060
	2004	91.49	17.57	68.98	20.43	-0.84	25.2	0.411

Table 10. Variables in best-fit models of multiple regression to predict capture rates within forest patches for raccoon, opossum and both mesocarnivores in 2003 and 2004 on Cross Timbers Experimental Range, Payne County, Oklahoma.

	Raccoon			Opossum			Total Mesocarnivores		
Variable	Coefficient	SE	Pr > F	Coefficient	SE	Pr > F	Coefficient	SE	Pr > F
Mixed forest (%)	297.55	96.69	0.008						
Distance to Paved Road (m)	0.001	0.0002	< 0.001				0.0004	0.0002	
Distance to Improved Road (m)	0.003	0.002	0.043						
Distance to Dirt Road (m)	0.005	0.003	0.131	0.01	0.004	0.002			
Patch Size (ha)							-0.1	0.03	0.065
Paved Highway (%)							180.17	43.41	0.001
Distance to Any Road (m)							0.02	0.005	< 0.001

Table 11. Variables in best-fit models of multiple regression to predict scent-station visitation within forest patches for raccoon, opossum and both mesocarnivores in 2003 and 2004 on Cross Timbers Experimental Range, Payne County, Oklahoma.

	Raccoon			Opossum			Total Mesocarnivores		
Variable	Coefficient	SE	Pr > F	Coefficient	SE	Pr > F	Coefficient	SE	Pr > F
Patch Size (ha)	-4.86	1.38	0.003						
Distance to Other Patch (m)	-2.36	0.83	0.013						
Distance to Improved Road (m)	-0.15	0.07	0.04	0.22	0.1	0.042			
Evergreen Forest (%)				-757.36	294.06	0.02			
Distance to Any Road (m)							0.64	0.39	0.122

Figure 1. Oak forest patches selected for mesocarnivore study within the Cross Timbers Experimental Range, Payne County, Oklahoma, 2003-2004.

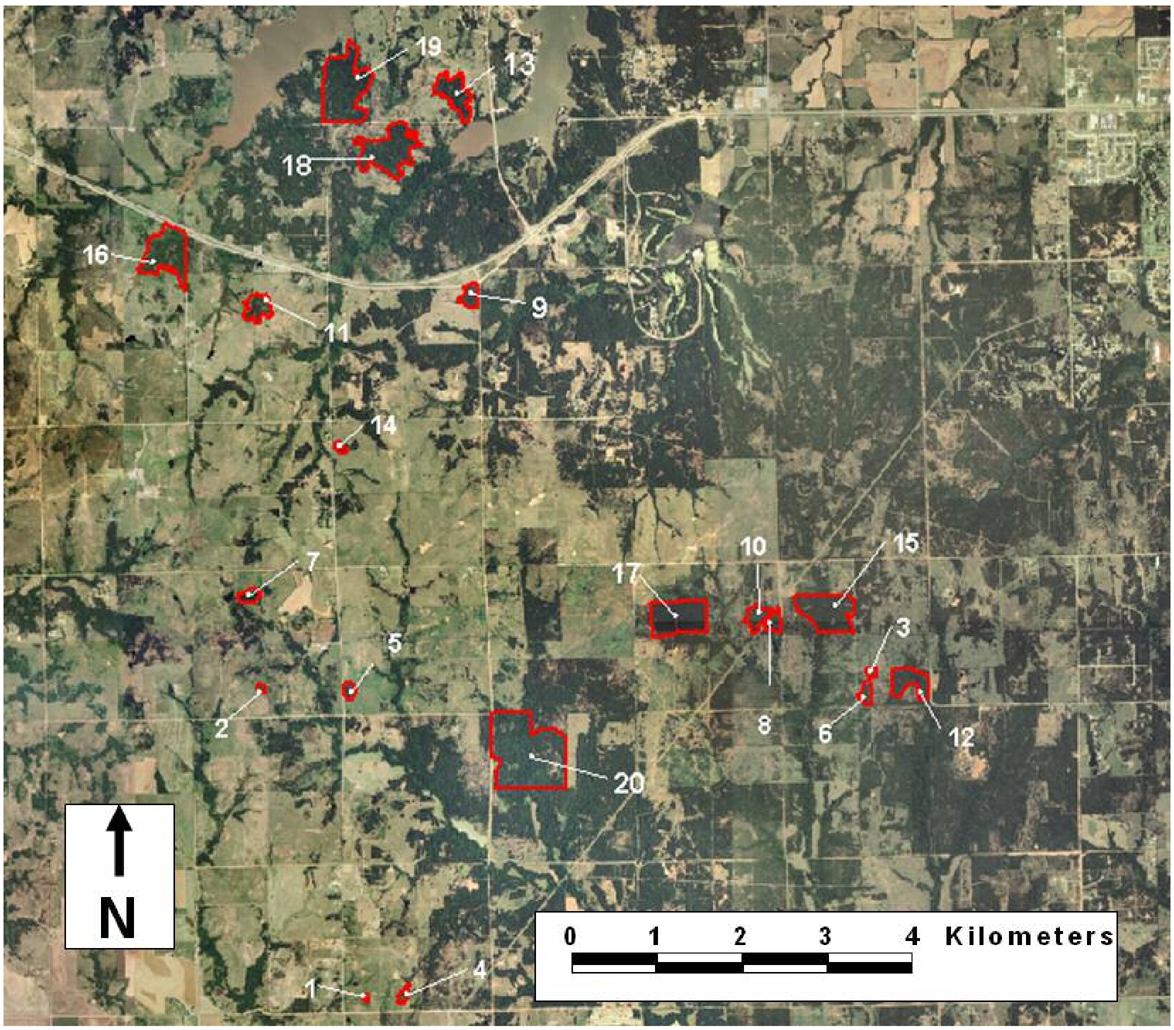

19
13
18
16
9
11
14
10
15
17
7
3
5
2
8
6
12
20
N
0 1 2 3 4 Kilometers
1
4

Figure 2. Example of microhabitat vegetation sampling at trap and scent station points on Cross Timbers Experimental Range, Payne County, Oklahoma.

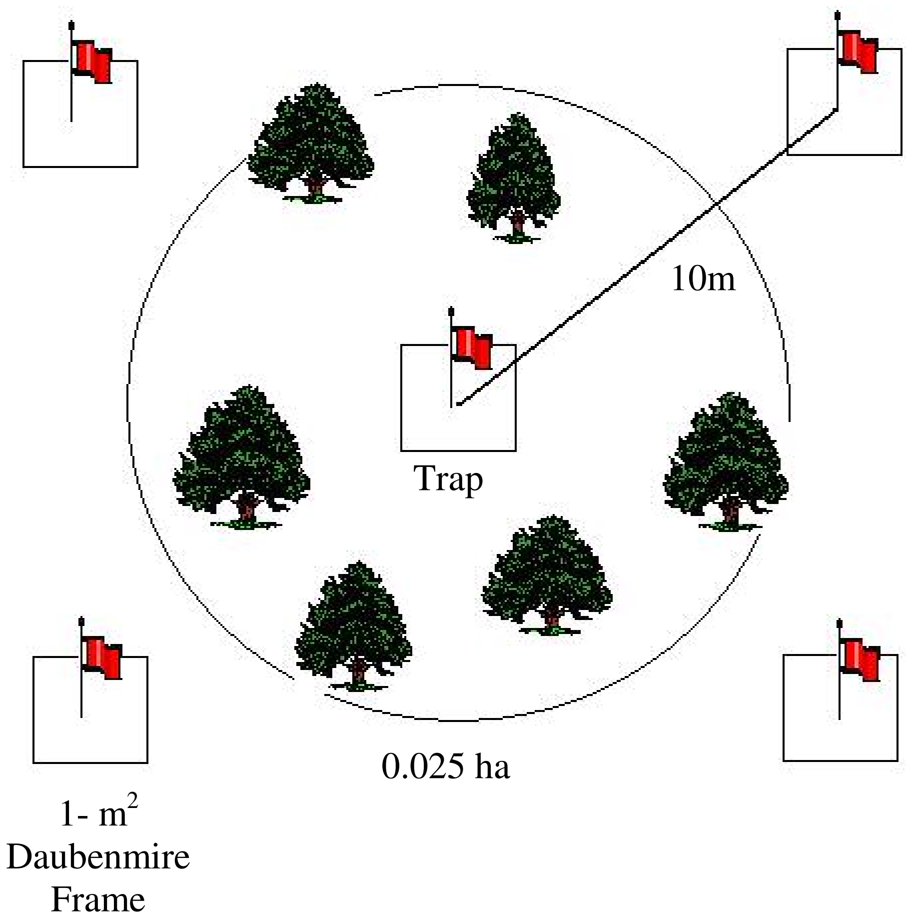
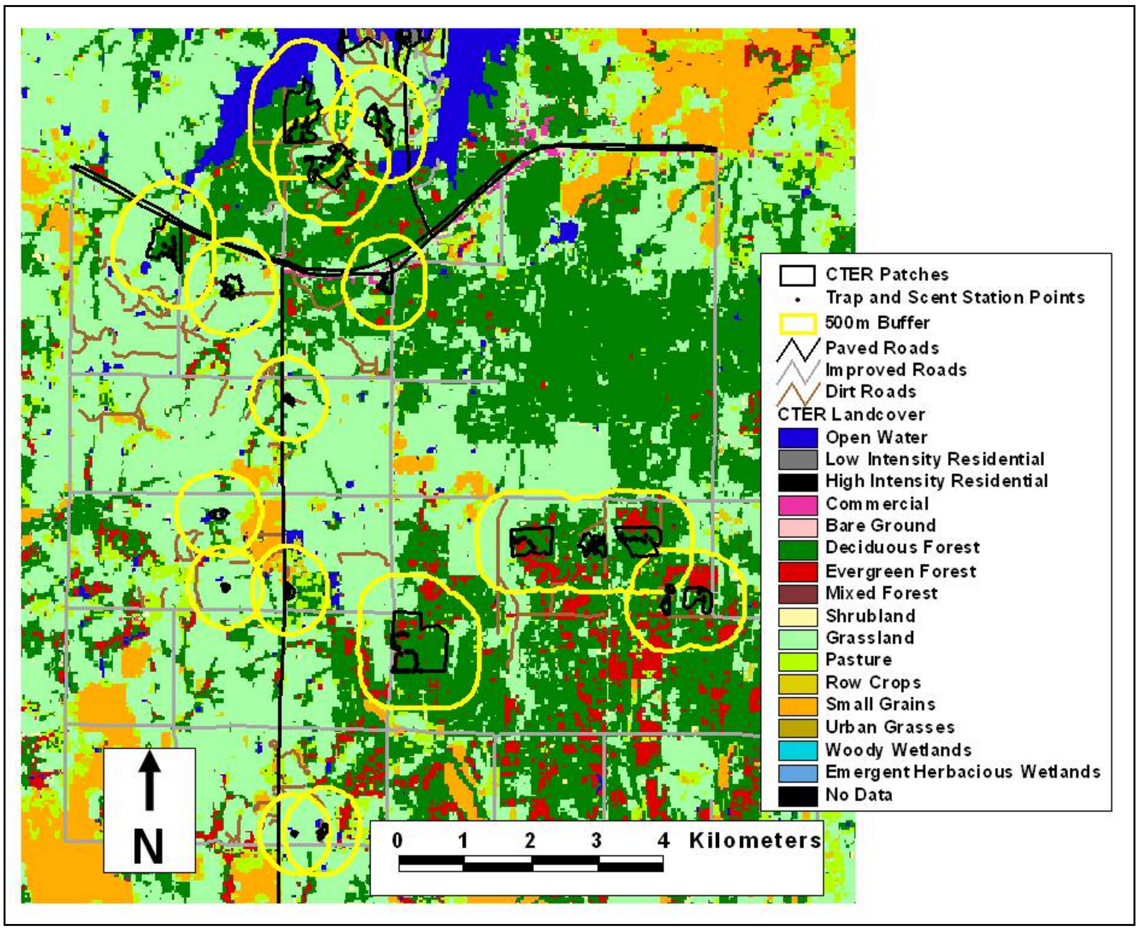
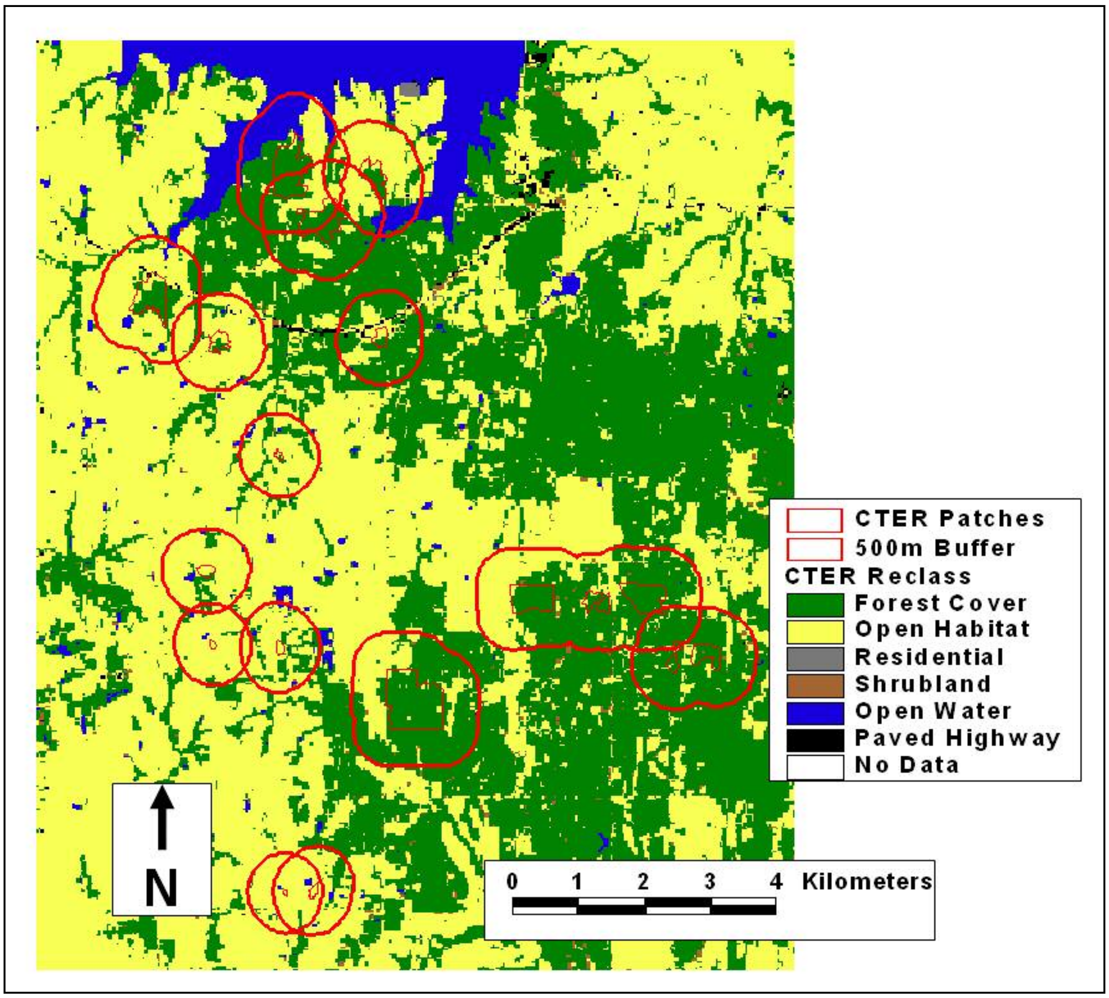

10m
Trap
0.025 ha
1- m2
Daubenmire
Frame

Figure 3. Oak forest patches and Landsat TM image of Cross Timbers Experimental Range, Payne County, Oklahoma, 2003



CTER Patches
Trap and Scent Station Points
500m Buffer
Paved Roads
Improved Roads
Dirt Roads
CTER Landcover
Open Water
Low Intensity Residential
High Intensity Residential
Commercial
Bare Ground
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrubland
Grassland
Pasture
Row Crops
Small Grains
Urban Grasses
Woody Wetlands
Emergent Herbacious Wetlands
No Data
N
0 1 2 3 4 Kilometers

Figure 4. Reclassified Landsat TM satellite image of Cross Timbers Experimental Range, Payne County, Oklahoma.



CTER Patches
500m Buffer
CTER Reclass
Forest Cover
Open Habitat
Residential
Shrubland
Open Water
Paved Highway
No Data
N
0
1
2
3
4
Kilometers

Figure 5. Linear regression of scent-station RAI and live-trapping capture rate for (a) raccoons, (b) opossums and (c) both species combined ($y = 0.01x + 8.4$) on Cross Timbers Experimental Range, Payne County, Oklahoma, 2003. Regression statistics are provided in the text.

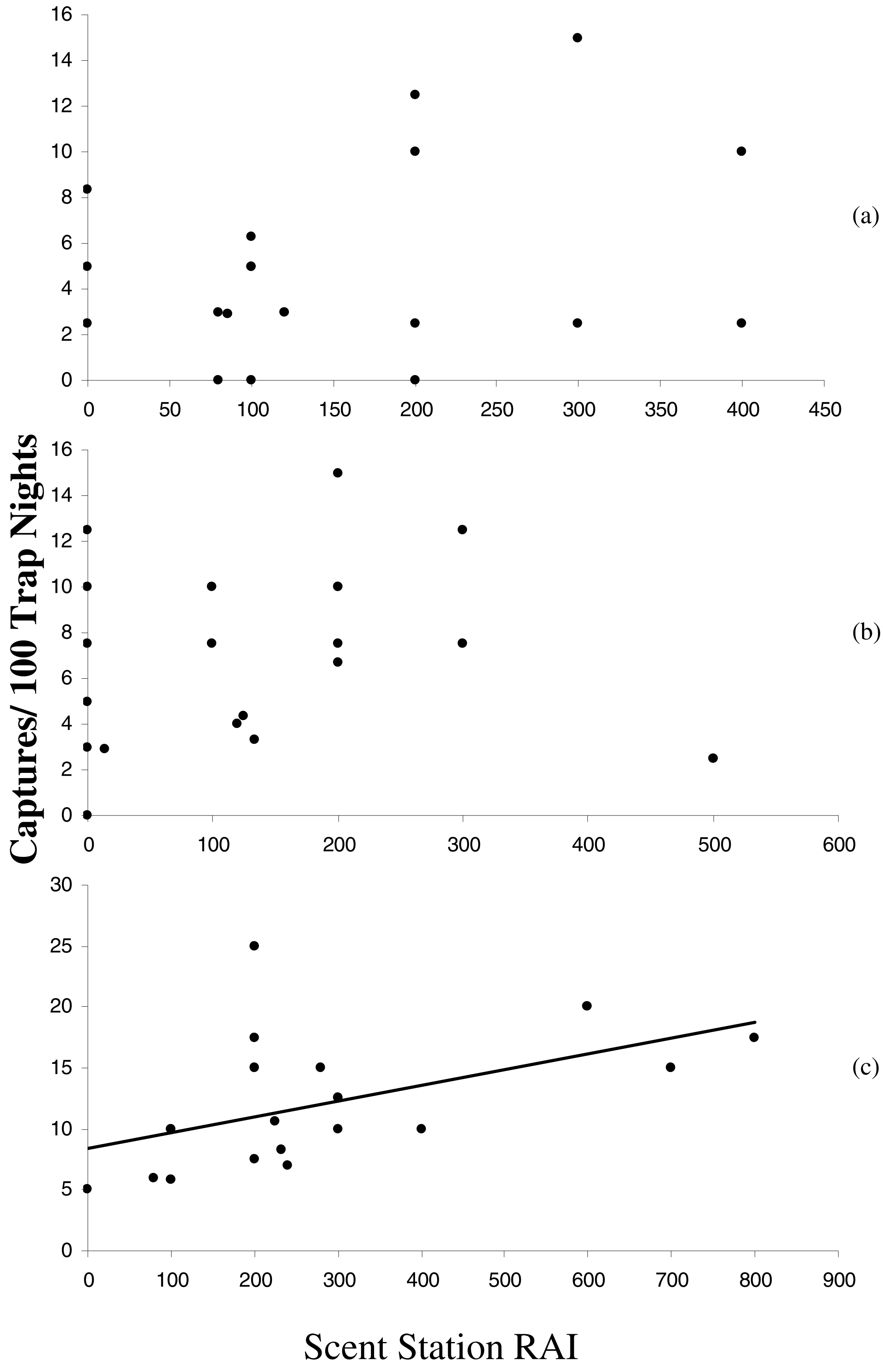

Captures/ 100 Trap Nights
(a)
(b)
(c)
Scent Station RAI

Figure 6. Linear regression of scent-station RAI and live-trapping capture rate for (a) raccoons, (b) opossums, and (c) both species combined on Cross Timbers Experimental Range, Payne County, Oklahoma, 2004. Regression statistics are provided in the text.

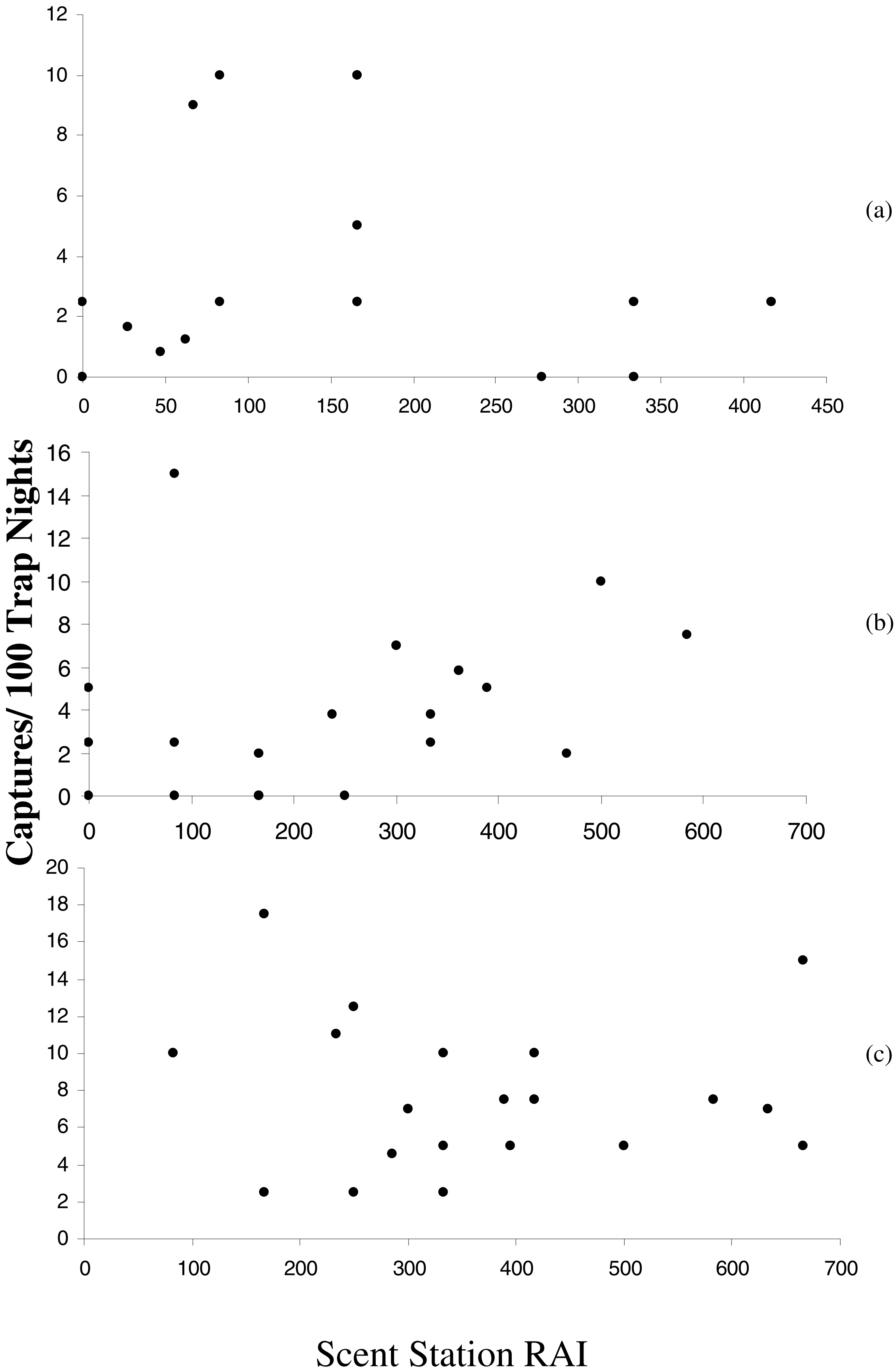
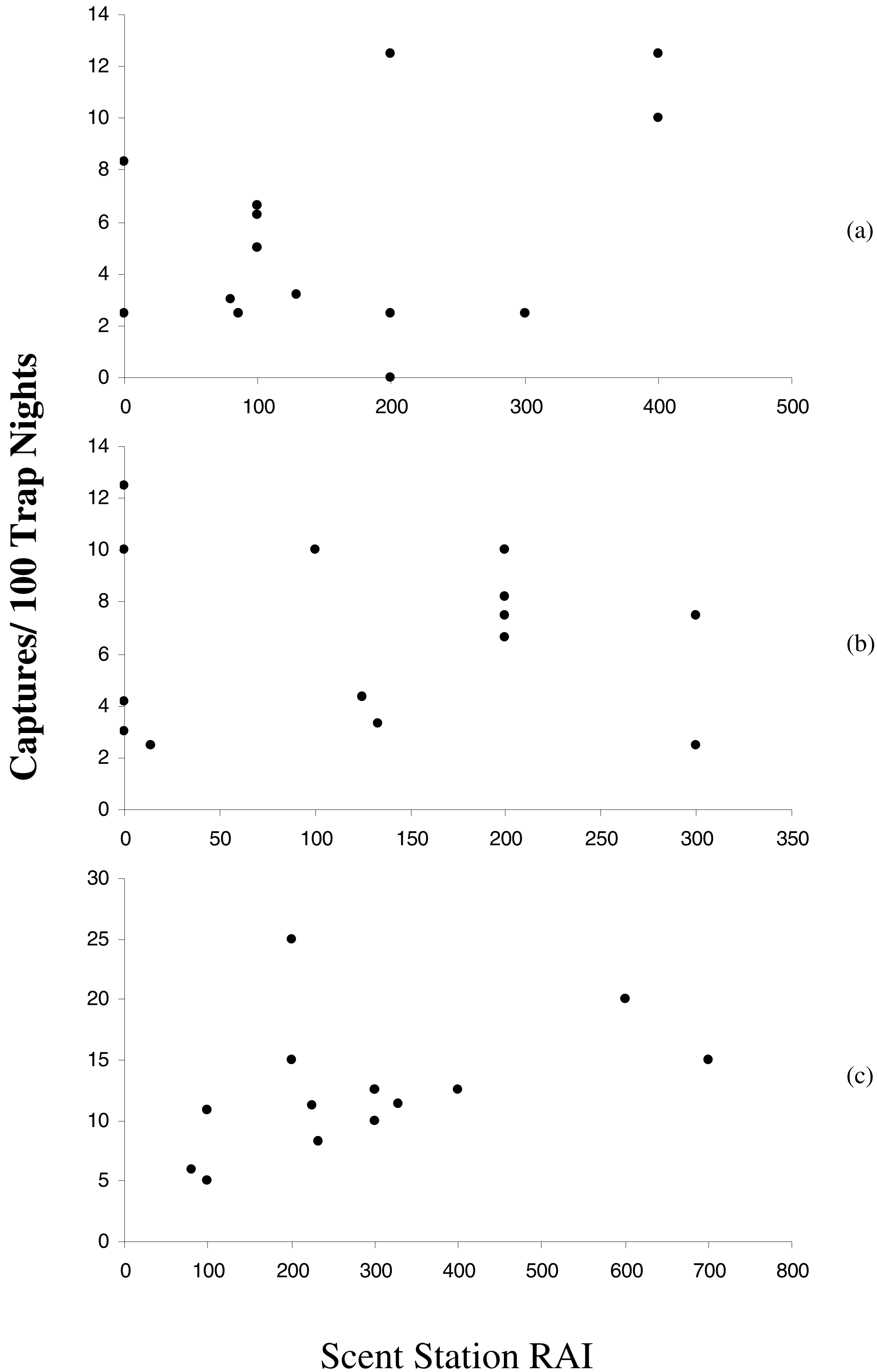

Captures/ 100 Trap Nights
(a)
(b)
(c)
Scent Station RAI

Figure 7. Linear regression of scent-station RAI and live-trapping capture rate for (a) raccoons, (b) opossums and (c) both species combined on Cross Timbers Experimental Range, Payne County, Oklahoma, 2003 in 15 independent patches. Regression statistics are provided in the text.



Captures/ 100 Trap Nights
(a)
(b)
(c)
Scent Station RAI

Figure 8. Linear regression of scent-station RAI and live-trapping capture rate for (a) raccoons, (b) opossums and (c) both species combined on Cross Timbers Experimental Range, Payne County, Oklahoma, 2004 in 15 independent patches. Regression statistics are provided in the text.

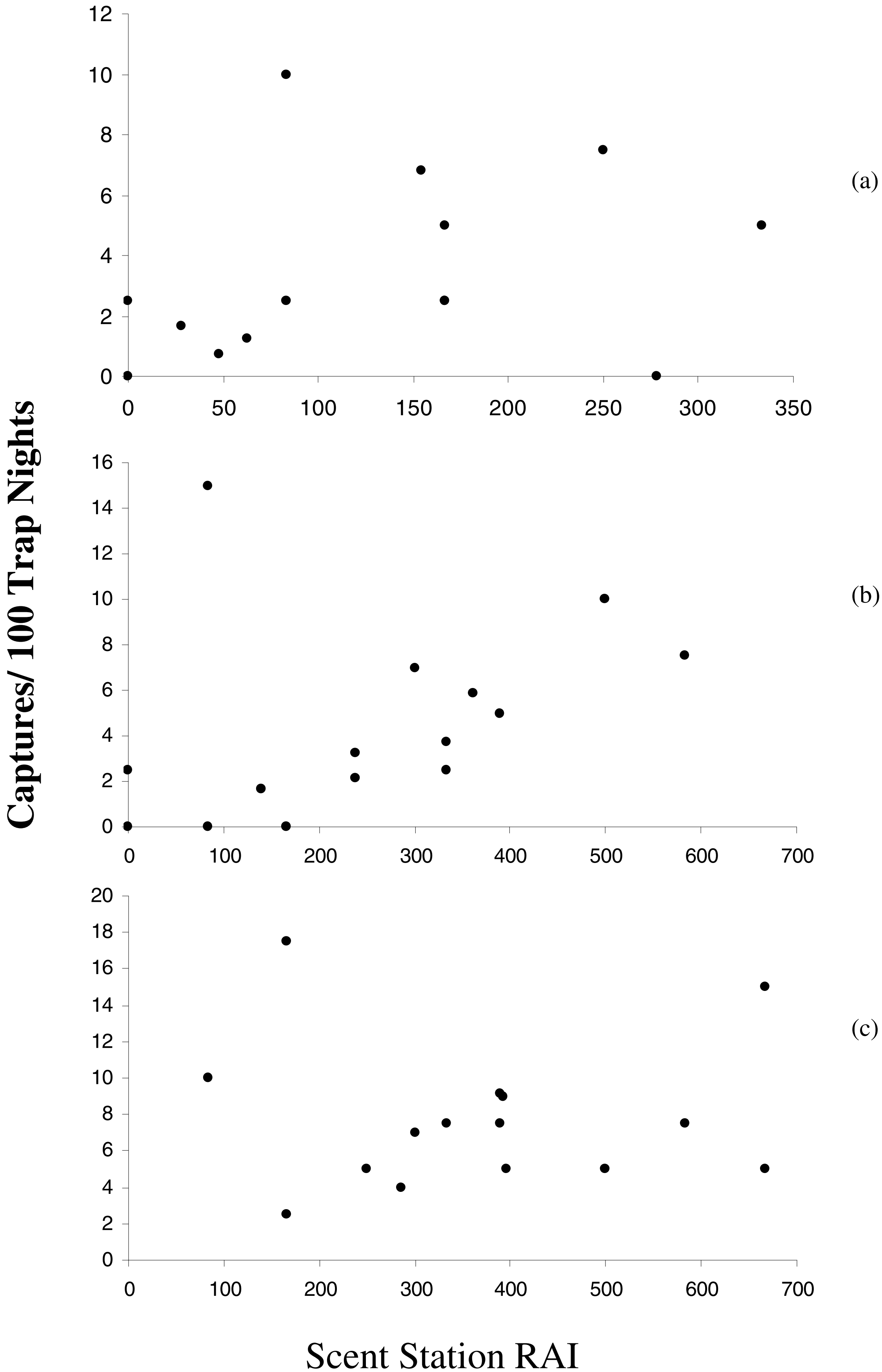
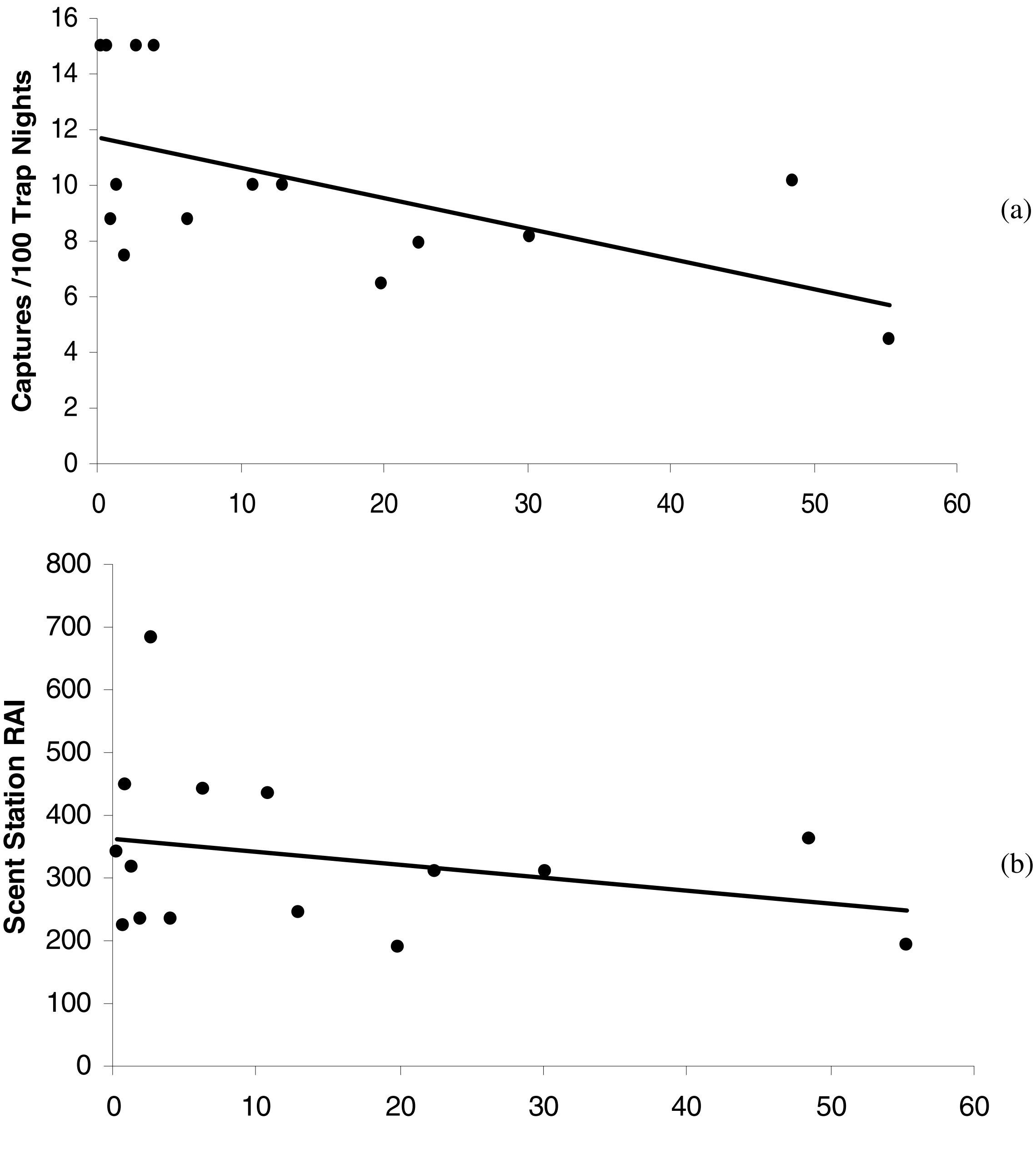
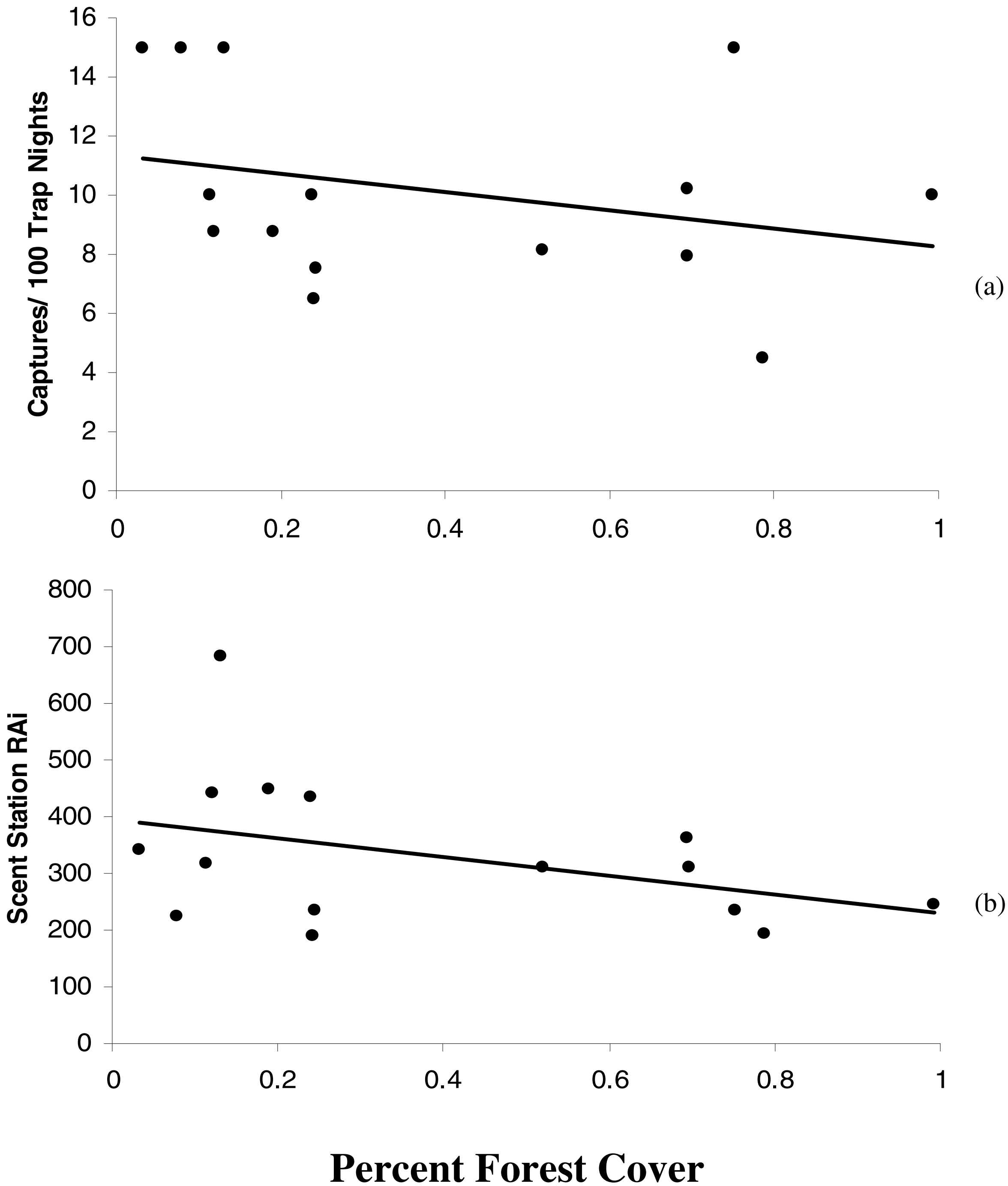

Captures/ 100 Trap Nights
Scent Station RAI
(a)
(b)
(c)

Figure 9. Linear regression of live-trapping capture rate (a; y = -0.109x + 11.73) and scent-station RAI (b; y = -2.05x + 361.07) against oak forest patch size for raccoons and opossums on Cross Timbers Experimental Range, Payne County, Oklahoma, 2003-2004 in 15 independent patches. Regression statistics are provided in the text.



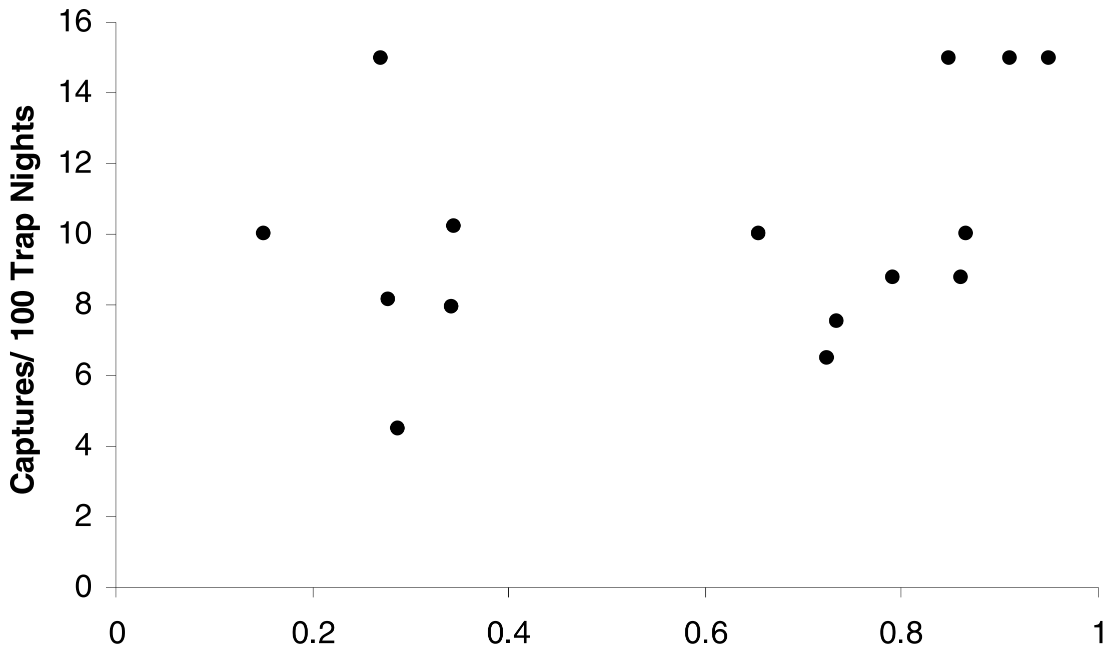
Oak Forest Patch Size

Figure 10. Linear regression of live-trapping capture rate (a; $y = -3.12x + 11.36$) and scent-station RAI (b; $y = -166.64x + 396.01$) against percent forest cover for raccoons and opossums on Cross Timbers Experimental Range, Payne County, Oklahoma, 2003-2004 in 15 independent patches. Regression statistics are provided in the text.

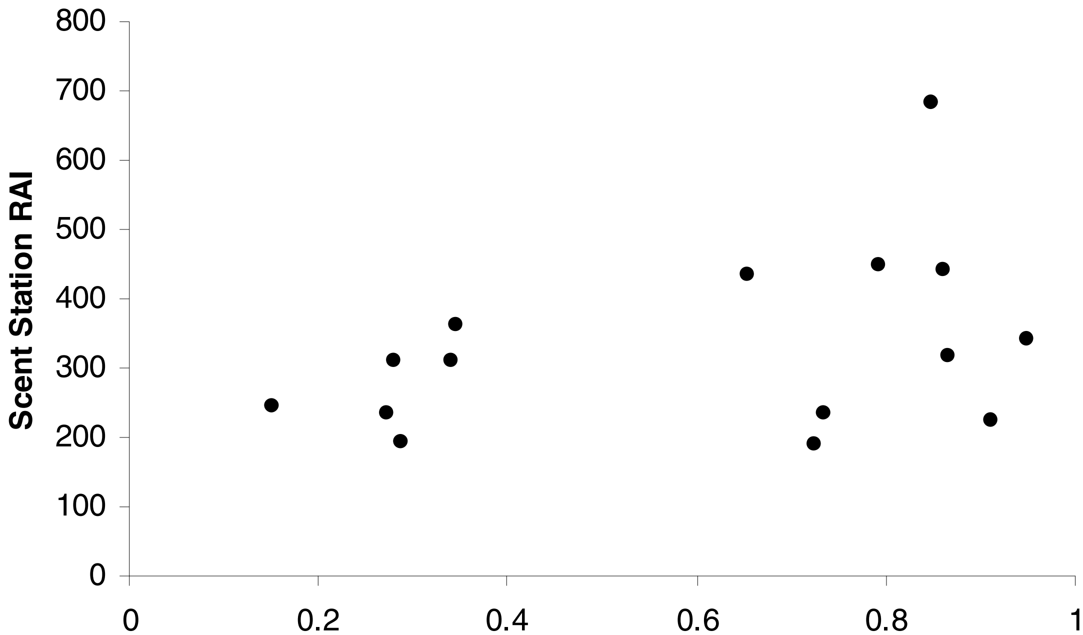


Captures/ 100 Trap Nights
0
2
4
6
8
10
12
14
16
0
0.2
0.4
0.6
0.8
1
(a)
Scent Station RAi
0
100
200
300
400
500
600
700
800
0
0.2
0.4
0.6
0.8
1
(b)
Percent Forest Cover

Figure 11. Linear regression of (a) live-trapping capture rate and (b) scent-station RAI against percent open habitat for raccoons and opossums on Cross Timbers Experimental Range, Payne County, Oklahoma, 2003-2004 in 15 independent patches. Regression statistics are provided in the text.



(a)



(b)

Percent Open Habitat

Appendix A

Number of shared captures of raccoons and opossums in oak forest patches in 2003-2004 on Cross Timbers Experimental Range, Payne County, Oklahoma.

	Unique Captured (n)			shared	Reference number	% caught in
Patch	Raccoon	Opossum	Total	captures (n)	of other patch(es)	> 1 Patch
1	8	4	12	0	0	0.0
2	6	5	11	0	0	0.0
3	6	0	6	3	12,6	50.0
4	3	5	8	0	0	0.0
5	3	3	6	0	0	0.0
6	6	2	8	3	3,12	37.5
7	7	5	12	0	0	0.0
8	7	2	9	3	15,17	33.3
9	2	10	12	1	14	8.3
10	4	4	8	3	15,17	37.5
11	1	6	7	0	0	0.0
12	5	5	10	2	3,6	20.0
13	5	7	12	1	18	8.3
14	1	5	6	1	9	16.7
15	12	6	18	3	10,17	16.7
16	3	10	13	0	0	0.0
17	5	17	22	5	10,15,8	22.7
18	8	11	19	2	13,19	10.5
19	12	13	25	1	18	4.0
20	9	16	25	0	0	0.0

VITA

Michael Roy Disney

Candidate for the Degree of

Master of Science

Thesis: MESOPREDATOR ABUNDANCE IN OAK FOREST PATCHES: A COMPARISON OF SCENT STATION AND LIVE-TRAPPING TECHNIQUES

Major Field: Wildlife and Fisheries Ecology

Biographical:

Personal Data: born in Muskogee, Oklahoma on December 14, 1977, to Kermit and Carolyn Robertson. Step-father Ed Disney, Tulsa, Oklahoma. Married May 28, 2000 to Brooke Nicole Griffith.

Education: graduated from Union High School, Tulsa, OK, May 1996; Received Bachelor of Science degree in Wildlife and Fisheries Ecology and a Minor in Forestry from Oklahoma State University, May 2001; completed requirements for Master of Science degree with a major in Wildlife and Fisheries Ecology and a Certificate in GIS at Oklahoma State University, July, 2005.

Experience: Park Ranger for Army Corps of Engineers at Heyburn Lake, Kellyville, Oklahoma, Summer 1999; Graduate Teaching Assistantship for Oklahoma State University, Stillwater, OK 2002-2004; Field Technician on swift fox and black bear projects for Oklahoma Cooperative Fish and Wildlife Research Unit of Stillwater, OK 2002-2005; National Science Foundation Fellowship in Department of Geography, Oklahoma State University, 2004-2005.

Professional Memberships:

- The Wildlife Society
- Vice President and Program Coordinator for Student Chapter of The Wildlife Society, Oklahoma State University
- President Zoology Graduate Student Society, Oklahoma State University.

Name: Michael Roy Disney Date of Degree: July 2005

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: MESOPREDATOR ABUNDANCE IN OAK FOREST PATCHES: A COMPARISON OF SCENT STATION AND LIVE-TRAPPING TECHNIQUES

Pages in Study: 80 Candidate for the Degree of Master of Science

Major Field: Wildlife and Fisheries Ecology

Scope and Method of Study: Forest- agricultural edges provide significant habitat to mesopredators. Growing concern within the scientific community over mesopredator abundance along these edges exists because nesting birds may become easy prey for foraging mesopredators (e.g. raccoon [*Procyon lotor*], Virginia opossum [*Didelphis virginiana*], striped skunk [*Mephitis mephitis*]). Patch size is a variable of interest in evaluating relationships between nest predation and mesopredator abundance because smaller patches are associated with more edge. We delineated 20 patches of oak forest ranging in size from 0.2 to 55.3 ha within the Oklahoma Crosstimbers Ecoregion, a mosaic of grassland and woodland, with the use of aerial photos and vector GIS. Scent stations and live traps were placed at a density of 0.25 – 0.50/ha within these patches to index mesopredator abundance in the summers of 2003 and 2004. I examined relationships of microhabitat and macrohabitat features with mesopredator capture and visitation rates within the forest patches.

Findings and Conclusions: No microhabitat variable was correlated consistently with mesopredator abundance for either year of the study. Macrohabitat landscape features correlated with mesopredator abundance included distance to roads (positive relationship) and patch size (negative). Mesopredator relative abundance indices from live trapping and scent stations were not highly correlated in either year of the study. These results suggest that the two methods may not be providing the same information. Our evidence that mesopredators within the Oklahoma crosstimbers were more likely to be found in smaller patches of oak woodland has implications to avian nesting success in these patches.

ADVISER'S APPROVAL: Eric C. Hellgren